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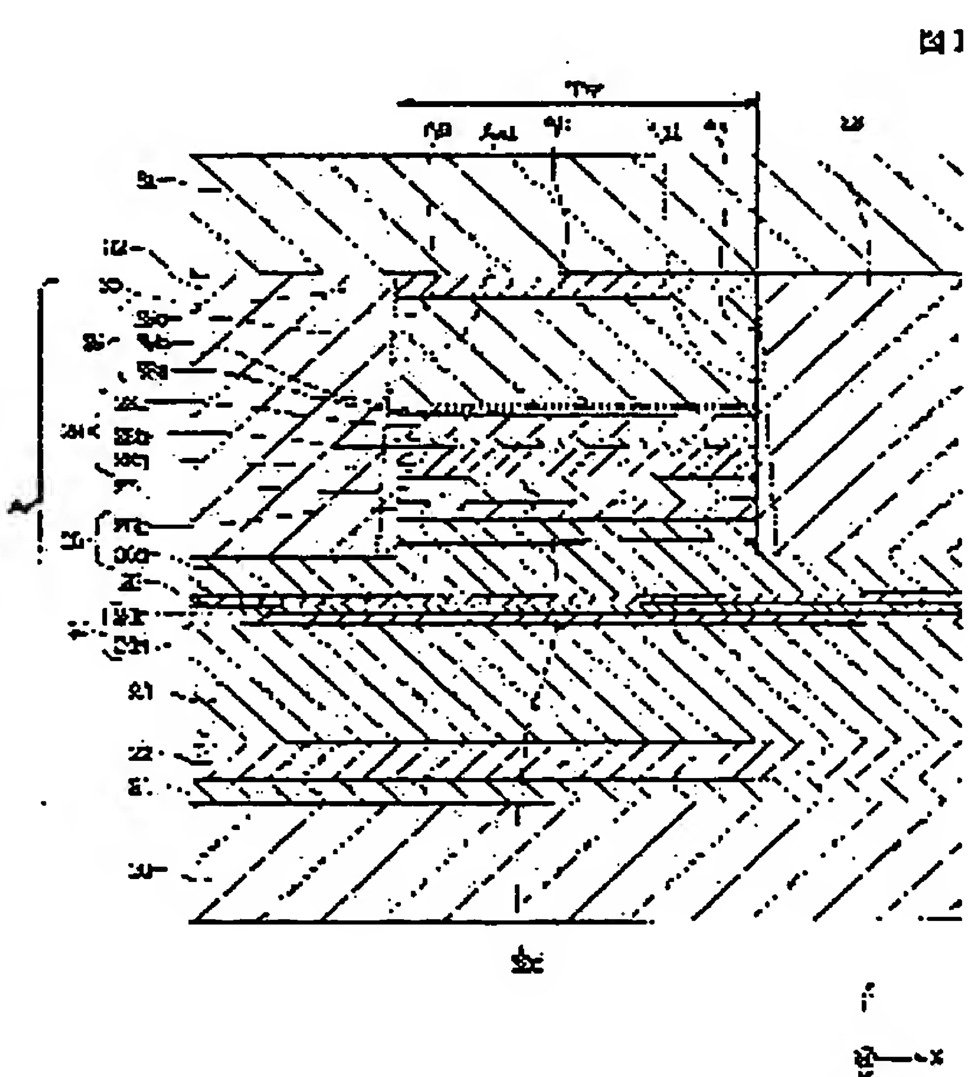
(54) MAGNETIC DETECTION ELEMENT AND ITS MANUFACTURING METHOD

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a magnetic detection element that appropriately and easily changes a free magnetic layer into a single magnetization domain and properly and easily controls a magnetizing direction, and promotes the achievement of a narrower track.
SOLUTION: The magnetizing direction of a ferromagnetic layer 24 is pinned by the exchange coupling magnetic field between a second antiferromagnetic layer 23 and the ferromagnetic layer 24, and the magnetizing direction of a free magnetic layer 26 is directed to a direction crossing the magnetizing direction of a pinned magnetic layer 28 by the RKKY mutual interaction of the ferromagnetic layer 24 and free magnetic layer 26 via a non-magnetic layer 25. Control in the magnetizing direction of the free magnetic layer 26 is adjusted by two stages of the intensity of the exchange coupled magnetic field between the second antiferromagnetic layer 23 and the ferromagnetic layer 24 and the intensity of the RKKY interaction between the ferromagnetic layer 24 and the free magnetic layer 26, thus easily carrying out fine control.



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* NOTICES *

CLAIMS

[Claim(s)]
[Claim 1] In the magnetic sensing element which has the multilayers which have the 1st antiferromagnetism layer, the fixed magnetic layer to which the magnetization direction was fixed by this 1st antiferromagnetism layer and a non-magnetic material layer, and the free magnetic layer from which the magnetization direction changes with external magnetic fields Said fixed magnetic layer and said free magnetic layer have the ferromagnetic ingredient layer which consists of a ferromagnetic ingredient. Said free magnetic layer at least in the upper layer or the lower layer of a width-of-recording-track field The magnetic sensing element which the laminating of a ferromagnetic layer and the 2nd antiferromagnetism layer is carried out through the non-magnetic layer, and is characterized by being turned in the dirèction where the magnetization direction of said ferromagnetic layer intersects the magnetization direction of said fixed magnetic layer by the switched connection field with said 2nd antiferromagnetism layer.
[Claim 2] Said free magnetic layer is a magnetic sensing element according to claim 1 by which it is single-domain-ized by the layer joint field through said non-magnetic layer with said ferromagnetic layer, and the magnetization direction is turned in the magnetization direction of said fixed magnetic layer, and the crossing direction.
[Claim 3] The magnetic sensing element according to claim 1 or 2 in which said non-magnetic layer is formed with one sort or two sorts or more of alloys among Ru, Rh, Ir, Cr, Re, and Cu.
[Claim 4] The magnetic sensing element according to claim 3 whose thickness said non-magnetic layer is formed of Ru, and is 8A - 11A or 15A - 21A.
[Claim 5] A magnetic sensing element according to claim 2 to 4 with the magnitude of the layer joint field between said free magnetic layer through said non-magnetic layer, and said ferromagnetic layer smaller than the magnitude of the switched connection field between said 2nd antiferromagnetism layers and said ferromagnetic layers.
[Claim 6] A magnetic sensing element according to claim 1 to 5 with the magnitude (Msxt) of the magnetic moment per unit area of said ferromagnetic layer smaller than the magnitude (Msxt) of the magnetic moment per unit area of said free magnetic layer.
[Claim 7] The magnetic sensing element according to claim 6 whose ratio of the magnitude (Msxt) of the magnetic moment per [to the magnitude (Msxt) of the magnetic moment per unit area of said ferromagnetic layer] unit area of said free magnetic layer is 20 or less range or more in three.
[Claim 8] The side to which said ferromagnetic layer touches said non-magnetic layer is a NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt). The magnetic sensing element according to claim 1 to 7 which has the laminated structure which is the layer which consists of a ferromagnetic ingredient with which the side which touches said 2nd antiferromagnetism layer contains Co (cobalt).
[Claim 9] The magnetic sensing element according to claim 1 to 7 whose thickness it is the monolayer structure where said ferromagnetic layer consists of NiFe (permalloy), and is 3nm or less more greatly than 0nm.
[Claim 10] Said ferromagnetic layer is a magnetic sensing element according to claim 1 to 7 which is the monolayer structure which consists of CoFeCr or CoFe.
[Claim 11] The magnetic sensing element according to claim 1 to 10 to which the magnetic field which becomes the side which touches said non-magnetic layer at least from a NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) exists in said free magnetic layer.
[Claim 12] The magnetic sensing element according to claim 11 in which the magnetic field which becomes said free magnetic layer from the ferromagnetic ingredient which contains Co (cobalt) in the side which touches said non-magnetic material layer exists.
[Claim 13] The magnetic sensing element according to claim 8 or 12 whose ferromagnetic ingredient containing said Co is CoFe or CoFeCr.

[Claim 14] Regeneration efficiency eta (%) is a magnetic sensing element according to claim 1 to 13 which is 50% or less at 10% or more.
[Claim 15] The magnetization direction of the width-of-recording-track field of said free magnetic layer is a magnetic sensing element according to claim 1 to 14 which inclines 12 degrees or more to the magnetization direction when the external magnetic field is not impressed, when an external magnetic field is impressed.
[Claim 16] Said multilayers are magnetic sensing elements according to claim 1 to 15 by which the laminating is carried out from the bottom in the sequence of said 1st antiferromagnetism layer, said fixed magnetic layer, said non-magnetic material layer, said free magnetic layer, said non-magnetic layer, said ferromagnetic layer, and said 2nd antiferromagnetism layer.
[Claim 17] Said multilayers are magnetic sensing elements according to claim 1 to 15 by which the laminating is carried out from the bottom in the sequence of said 2nd antiferromagnetism layer, said ferromagnetic layer, said non-magnetic layer, said free magnetic layer, said non-magnetic material layer, said fixed magnetic layer, and said 1st antiferromagnetism layer.
[Claim 18] Said free magnetic layer is a magnetic sensing element according to claim 17 in which a part of direction of thickness has the truck cross direction dimension of a truck width method, and it has a truck cross direction dimension with the larger remaining part than a truck width method.
[Claim 19] Said free magnetic layer is a magnetic sensing element according to claim 1 to 18 which is in the ferrimagnetism condition that the magnetization direction of said ferromagnetic ingredient layer where the laminating of two or more ferromagnetic ingredient layers from which the magnitude of the magnetic moment per unit area differs is carried out through a nonmagnetic interlayer, and they adjoin through said nonmagnetic interlayer serves as anti-parallel.
[Claim 20] Said nonmagnetic interlayer is a magnetic sensing element according to claim 19 currently formed with one sort or two sorts or more of alloys among Ru, Rh, Ir, Cr, Re, and Cu.
[Claim 21] The magnetic sensing element according to claim 19 or 20 which forms at least one layer of said two or more ferromagnetic ingredient layers with the magnetic material which has the following presentations. It is the magnetic material whose remaining presentation ratios an empirical formula is shown by CoFeNi, the presentation ratio of Fe is below 17 atom % more than 9 atom %, the presentation ratio of nickel is below 10 atom % more than 0.5 atom %, and are Co(es).
[Claim 22] The magnetic sensing element according to claim 19 or 20 which forms the interlayer who consists of a CoFe alloy or Co between said ferromagnetic ingredient layer by which the laminating was carried out to the location nearest to said non-magnetic material layer, and said non-magnetic material layer.
[Claim 23] The magnetic sensing element according to claim 22 which forms at least one layer of said two or more ferromagnetic ingredient layers with the magnetic material which has the following presentations. It is the magnetic material whose remaining presentation ratios an empirical formula is shown by CoFeNi, the presentation ratio of Fe is below 15 atom % more than 7 atom %, the presentation ratio of nickel is below 15 atom % more than pentatomic %, and are Co(es).
[Claim 24] The magnetic sensing element according to claim 21 or 23 which forms all the layers of two or more of said ferromagnetic ingredient layers by said CoFeNi.
[Claim 25] The magnetic sensing element according to claim 1 to 24 by which an up electrode layer is electrically connected to the top face of said multilayers, a lower electrode layer is electrically connected to the inferior surface of tongue of said multilayers, and a current is supplied to the film surface and perpendicular direction of said multilayers.
[Claim 26] The magnetic sensing element according to claim 1 to 25 in which said multilayers have a semimetal ferromagnetism Heusler alloy layer.
[Claim 27] The magnetic sensing element according to claim 26 to which the NiFe layer is in contact with said semimetal ferromagnetism Heusler alloy layer.
[Claim 28] The magnetic sensing element according to claim 1 to 27 currently formed with the antiferromagnetism ingredient with which said 1st antiferromagnetism layer and said 2nd antiferromagnetism layer have the same presentation.
[Claim 29] Said 1st antiferromagnetism layer and/or said 2nd antiferromagnetism layer A PtMn alloy, Or it is a X-Mn (however, X is one-sort [any] or two sorts or more of elements of Pd, Ir, Rh, Ru, Os, nickel, and Fe) alloy, or is Pt-Mn-X' (however, X'). The magnetic sensing element according to claim 1 to 28 formed with the alloy which are any one sort or two sorts or more of elements of Pd, Ir, Rh, Ru, Au, Ag, Os, Cr, nickel, Ar, Ne, Xe, and Kr.
[Claim 30] As for said multilayers, the laminating of a ferromagnetic layer and said 2nd antiferromagnetism layer is carried out to said free magnetic layer top or bottom through said non-magnetic layer. A fixed magnetic layer is formed in the both-sides end face of the truck cross direction of said free magnetic layer through a non-magnetic material layer at least. A magnetic sensing element given in either claim 1 which is the structure where the laminating of said 1 antiferromagnetism layer was carried out and by which an electrode layer is formed on said 1st

antiferromagnetism layer on said fixed magnetic layer 15 and 19 21, 23, 24 and 26 thru/or 29.
[Claim 31] The manufacture approach of the magnetic sensing element characterized by having the following processes.
(a) The process which carries out a laminating to the order of a 2nd antiferromagnetism layer, ferromagnetic layer, non-magnetic layer, free magnetic layer, and non-magnetic material layer, a fixed magnetic layer, a middle antiferromagnetism layer, and a nonmagnetic protective layer from the bottom on a substrate, (b) The process which gives 1st annealing in a magnetic field, is made to generate a switched connection field between said 2nd antiferromagnetism layers and said ferromagnetic layers, and fixes magnetization of said ferromagnetic layer crosswise [truck], (c) The process which forms an up antiferromagnetism layer for said nonmagnetic protective layer all or the process deleted in part, and on the (d) aforementioned nonmagnetic protective layer or a middle antiferromagnetism layer, and forms the 1st antiferromagnetism layer which has said middle antiferromagnetism layer and said up antiferromagnetism layer, (e) Process which gives 2nd annealing in a magnetic field, is made to generate a switched connection field between said 1st antiferromagnetism layers and said fixed magnetic layers, and fixes magnetization of said fixed magnetic layer in the magnetization direction of said ferromagnetic layer, and the crossing direction.
[Claim 32] The manufacture approach of the magnetic sensing element according to claim 31 which forms said nonmagnetic protective layer by any one sort of Ru, Re, Pd, Os, Ir, Pt, Au, Rh, Cu, and the Cr, or two sorts or more.

[Claim 33] The manufacture approach of the magnetic sensing element according to claim 31 or 32 which forms said middle antiferromagnetism layer by 10A or more 50A or less at the aforementioned (a) process.
[Claim 34] The manufacture approach of the magnetic sensing element according to claim 33 which forms said middle antiferromagnetism layer by 30A or more 40A or less.
[Claim 35] The manufacture approach of the magnetic sensing element according to claim 31 to 34 which forms said nonmagnetic protective layer by 3A or more 10A or less at the aforementioned (a) process.
[Claim 36] The manufacture approach of a magnetic sensing element according to claim 31 to 35 of deleting said nonmagnetic protective layer or removing said all nonmagnetic protective layers at the aforementioned (c) process until the thickness of said nonmagnetic protective layer becomes 3A or less.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention mainly relates to the magnetic sensing element used for a magnetometric sensor, a hard disk, etc., and its manufacture approach, especially makes easy correspondence to the formation of narrow track width of face, and relates to the magnetic sensing element which can raise field ability to detect, and its manufacture approach.
[0002]
[Description of the Prior Art] Drawing 18 is the sectional view which looked at the structure of the conventional magnetic sensing element from the opposed face with a record medium.
[0003] The magnetic sensing element shown in drawing 18 is called the spin bulb mold MAG sensing element which is one sort using giant magneto-resistance of a GMR (giant magnetoresistive) component, and detects the record field from record media, such as a hard disk.
[0004] The multilayers 9 by which this spin bulb mold MAG sensing element was constituted from the bottom by a substrate 8, the 1st antiferromagnetism layer 1, the fixed magnetic layer (pin (Pinned) magnetic layer) 2, the non-magnetic material layer 3, and the free magnetic layer (Free) 4, It consists of electrode layers 7 and 7 of the pair formed the 2nd antiferromagnetism layers 6 and 6 of the pair formed in the upper layer of these multilayers 9, and on these 2nd antiferromagnetism layers 6 and 6.
[0005] Generally Cr film is used for Cu (copper) film and the electrode layers 7 and 7 by the nickel-Fe (nickel-iron) alloy film and the non-magnetic material layer 3 in said 1st antiferromagnetism layer 1 and the 2nd antiferromagnetism layers 6 and 6 at the Fe-Mn (iron-manganese) alloy film, the nickel-Mn (nickel-manganese) alloy film or the Pt-Mn (platinum-manganese) alloy film, the fixed magnetic layer 2, and the free magnetic layer 4.
[0006] Magnetization of the fixed magnetic layer 2 is single-domain-ized by the exchange anisotropy field with the 1st antiferromagnetism layer 1 in the direction (the direction of a leakage field from a record medium; the height direction) of Y, and, as for magnetization of the free magnetic layer 4, it is desirable to be arranged in the direction of X in response to the effect of the exchange anisotropy field from said 2nd antiferromagnetism layers 6 and 6.
[0007] That is, it is desirable for magnetization of the fixed magnetic layer 2 and magnetization of the free magnetic layer 4 to intersect perpendicularly.
[0008] In this spin bulb mold MAG sensing element, a detection current (sense current) is given to the free magnetic layer 4, the non-magnetic material layer 3, and the fixed magnetic layer 2 from the 2nd antiferromagnetism layer 6 and the electrode layers 7 and 7 formed on six. The transit direction of record media, such as a hard disk, is a Z direction, and if the leak field from a record medium is given in the direction of Y, magnetization of the free magnetic layer 4 will change from X towards the direction of Y. Electric resistance changes by the relation between fluctuation of the direction of magnetization within this free magnetic layer 4, and the fixed magnetization direction of the fixed magnetic layer 2 (this is called magneto-resistive effect), and the leak field from a record medium is detected by the electrical-potential-difference change based on this electric resistance value change.
[0009] Moreover, the approach as shown in drawing 20 later mentioned in addition to the approach shown in drawing 18 as a means to give a bias field to the free magnetic layer 4, and the approach of the following patent reference 1 etc. are learned variously.
[0010]
[Patent reference 1] USP6,023,395 [0011]
[Problem(s) to be Solved by the Invention] When manufacturing the spin bulb mold MAG sensing element of drawing 18 , after forming multilayers 9, as shown in drawing 19 , the resist layer R for lift off is formed on multilayers 9, and the 2nd antiferromagnetism layers 6 and 6 and the electrode layers 7 and 7 are formed using the ion beam spatter method etc. On the resist layer R, the layers 6a and 6a of the same presentation as the 2nd antiferromagnetism layers 6 and 6 and the layers 7a and 7a of the same presentation as the electrode layers 7 and 7

are formed.
[0012] As for the field covered with the both ends of the resist layer R, the laminating of the sputtered particles is hard to be carried out. Therefore, as thickness is formed thinly and the 2nd antiferromagnetism layers 6 and 6 and the electrode layers 7 and 7 are shown in drawing 18 and drawing 19 , as for near the field covered with the both ends of the resist layer R, the direction dimension of thickness of the 2nd antiferromagnetism layers 6 and 6 and the electrode layers 7 and 7 decreases in truck both the side parts S and S.
[0013] For this reason, the effectiveness of the switched connection field of the free magnetic layer 4 and the 2nd antiferromagnetism layers 6 and 6 in truck both the side parts S and S will decrease. Consequently, the magnetization direction of truck both the side parts S and S of the free magnetic layer 4 in drawing 19 is not completely fixed in the direction of X, but when an external magnetic field is impressed, it will change.
[0014] In order to raise the recording density in a magnetic-recording medium especially, when narrow track-ization was attained, there was a problem that possibility of reading the information not only on the information on the magnetic-recording truck which should be essentially read in the field of the width of recording track Tw but an adjoining magnetic-recording truck in the field of truck both the side parts S and S and that side leading will occur arose.
[0015] Moreover, single-domain-izing of the center section of the truck cross direction of the free magnetic layer 4 and control of the magnetization direction tend to become inadequate in case of the structure which carries out the laminating of the 2nd antiferromagnetism layers 6 and 6 of a pair on the both ends of the truck cross direction of the free magnetic layer 4.
[0016] Then, like the magnetic sensing element shown in drawing 18 , open the width of face of a truck width method on the both ends of the free magnetic layer 4, and the laminating of the 2nd antiferromagnetism layers 6 and 6 of a pair is not carried out. Like the magnetic sensing element shown in drawing 20 , by putting the 2nd antiferromagnetism layer 10 on the whole top face of the free magnetic layer 4, the field of the truck width method Tw of the free magnetic layer 4 was single-domain-ized, and the structure of making the magnetization direction turned in the direction which intersects perpendicularly in the magnetization direction of the fixed magnetic layer 1 was also considered.
[0017] Although it is necessary to enlarge the switched connection field between the free magnetic layer 4 and the 2nd antiferromagnetism layer 10 in order to single-domain-ize the field of the truck width method Tw of the free magnetic layer 4 and to make the magnetization direction turned in the direction which intersects perpendicularly in the magnetization direction of the fixed magnetic layer 1 If this switched connection field becomes large too much, when the leak field from a record medium is given in the direction of Y, magnetization of the free magnetic layer 4 will not change and magnetic ability to detect will be lost.
[0018] However, structure like drawing 20 was very difficult to adjust the magnitude of the switched connection field between the free magnetic layer 4 and the antiferromagnetism layer 10 in the range which it can leak [range] and can fluctuate the magnetization direction of the free magnetic layer 4 by the field towards the direction which intersects perpendicularly the magnetization direction of the free magnetic layer 4 in the magnetization direction of the fixed magnetic layer 1, and was low. [of practicality]
[0019] Moreover, by the patent reference 1, the bias layer (biasing layer) is prepared through the spacer layer (spacer layer), for example on the free magnetic layer, and it is supposed by magnetostatic association between the edge of the truck cross direction of said bias layer, and the edge of the truck cross direction of said free magnetic layer that magnetization of said free magnetic layer will be single-domain-ized. The approach of arranging magnetization of said free magnetic layer using magnetostatic association between edges with a bias layer like the patent reference 1 is called the Instack bias method.
[0020] However, in the recent years which control of the thickness of said spacer layer for supplying a moderate bias field and control of the distance between the edges of a free magnetic layer and a bias layer are very difficult for a free magnetic layer, and component size has narrow-ized in an Instack bias method like the patent reference 1, it is still more so. since the edge of a free magnetic layer is especially influenced strongly of magnetostatic association compared with a center section, supply of a uniform bias field is not carried out to the whole free magnetic layer, but the edge of a free magnetic layer is magnetized strongly -- having -- here -- an insensible field -- becoming -- consequently, the center section of the free magnetic layer -- the magnetization interaction inside a magnetic layer -- an external magnetic field -- receiving -- reversed -- ****** -- **
[0021] Moreover, if component size is in the narrow-ized recent years, the bias field by said magnetostatic association tends to flow not only into said free magnetic layer but into other layers, and the problem of being easy to have a bad influence on reproducing characteristics also has it.
[0022] Then, this invention aims at offering the magnetic sensing element which it is, can perform appropriately and easily single-domain-izing of a free magnetic layer, and control of the magnetization direction, and can promote narrow track-ization and its manufacture approach for solving the above-mentioned conventional technical problem.

[0023]
[Means for Solving the Problem] In the magnetic sensing element which has the multilayers in which this invention has the 1st antiferromagnetism layer, the fixed magnetic layer to which the magnetization direction was fixed by this 1st antiferromagnetism layer and a non-magnetic material layer, and the free magnetic layer from which the magnetization direction changes with external magnetic fields Said fixed magnetic layer and said free magnetic layer have the ferromagnetic ingredient layer which consists of a ferromagnetic ingredient. Said free magnetic layer at least in the upper layer or the lower layer of a width-of-recording-track field The laminating of a ferromagnetic layer and the 2nd antiferromagnetism layer is carried out through the non-magnetic layer, and it is characterized by being turned in the direction where the magnetization direction of said ferromagnetic layer intersects the magnetization direction of said fixed magnetic layer by the switched connection field with said 2nd antiferromagnetism layer.

[0024] In this invention, it is turned in the direction where the magnetization direction of said ferromagnetic layer intersects the magnetization direction of said fixed magnetic layer by the switched connection field with said 2nd antiferromagnetism layer. Since the laminating of said free magnetic layer is carried out to said ferromagnetic layer through said non-magnetic layer, single-domain-izing of said free magnetic layer, and control of the magnetization direction It will be adjusted in two steps, the magnitude of the switched connection field between said antiferromagnetism layers and said ferromagnetic layers, and the magnitude of magnetic association between said ferromagnetic layers and said free magnetic layers, and fine control can be performed easily.

[0025] Therefore, in this invention, since single-domain-izing of said free magnetic layer and control of the magnetization direction can be performed appropriately and easily, the further narrow track-ization of a magnetic sensing element can be promoted.

[0026] moreover, the direction which intersects perpendicularly the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer by this invention also with the structure where the laminating of said ferromagnetic layer and said 2nd antiferromagnetism layer is carried out through said non-magnetic layer on the width-of-recording-track field of said free magnetic layer -- certain -- turning -- in addition -- and it becomes possible to leak and to fluctuate the magnetization direction of said free magnetic layer by the field.

[0027] Therefore, it can be made hard to be in the condition that the magnetization directions of said free magnetic layer differ, in this invention at the center section and both ends of a width-of-recording-track field of said free magnetic layer.

[0028] Moreover, in this invention, it is desirable that it is single-domain-ized by the layer joint field said free magnetic layer minded said non-magnetic layer with said ferromagnetic layer, and the magnetization direction is turned in the magnetization direction of said fixed magnetic layer and the crossing direction.

[0029] For example, between said free magnetic layers and said ferromagnetic layers, the RKKY interaction through said non-magnetic layer occurs. Consequently, said free magnetic layer single-domain-izes, and the magnetization direction is turned in the magnetization direction of said fixed magnetic layer, and the crossing direction.

[0030] Thus, in this invention, since single-domain-izing of said free magnetic layer and control of the magnetization direction are performed by the layer joint field through said non-magnetic layer with said ferromagnetic layer, the vertical bias field concerning said free magnetic layer can control that turbulence and the magnetic-domain structure of said free magnetic layer are disturbed by external magnetic fields, such as a leak field from a record medium.

[0031] In order to produce the RKKY interaction stabilized between said free magnetic layers and said ferromagnetic layers, it is desirable that said non-magnetic layer is formed with one sort or two sorts or more of alloys among Ru, Rh, Ir, Cr, Re, and Cu.

[0032] When changing into the artificial ferry condition of having formed said non-magnetic layer by Ru, and having changed the 180 degrees of the magnetization directions of said free magnetic layer and said ferromagnetic layer, it is desirable to make thickness of said Ru into 8A - 11A or 15A - 21A.

[0033] After enlarging the switched connection field between said 2nd antiferromagnetism layers and said ferromagnetic layers and fixing the magnetization direction of said ferromagnetic layer in the magnetization direction of said fixed magnetic layer, and the crossing direction strongly in this invention The magnitude of the layer joint field between said free magnetic layer through said non-magnetic layer, and said ferromagnetic layer by making it smaller than said switched connection field between said 2nd antiferromagnetism layers and said ferromagnetic layers the direction which intersects perpendicularly the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer -- certain -- turning -- in addition -- and it is necessary to adjust so that it can leak and the magnetization direction of said free magnetic layer can be fluctuated by the field

[0034] In order to enlarge the switched connection field between said 2nd antiferromagnetism layers and said ferromagnetic layers and to make magnitude of the layer joint field between said free magnetic layers and said

ferromagnetic layers smaller than said switched connection field In this invention, how to make magnitude (Msxt; product of saturation magnetic flux density and thickness) of the magnetic moment per unit area of said ferromagnetic layer smaller than the magnitude (Msxt; product of saturation magnetic flux density and thickness) of the magnetic moment per unit area of said free magnetic layer can be taken.
[0035] Specifically, it is desirable that the ratio of the magnitude (Msxt) of the magnetic moment per [to the magnitude (Msxt) of the magnetic moment per unit area of said ferromagnetic layer] unit area of said free magnetic layer is 20 or less range or more in three.
[0036] moreover By forming the side which touches said non-magnetic layer of said ferromagnetic layer by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) By forming the side which makes small moderately magnitude of the layer joint field between said free magnetic layers and said ferromagnetic layers, and touches said 2nd antiferromagnetism layer of said ferromagnetic layer with the ferromagnetic ingredient containing Co (cobalt) The switched connection field between said 2nd antiferromagnetism layers and said ferromagnetic layers can be enlarged.
[0037] or the direction which single-domain-izes said free magnetic layer, and intersects the magnetization direction perpendicularly in the magnetization direction of said fixed magnetic layer by making said ferromagnetic layer into the monolayer structure which consists of NiFe (permalloy) in this invention, and forming the thickness of said ferromagnetic layer as 3nm or less more greatly than 0nm -- certain -- turning -- in addition -- and it can leak and the magnetization direction of said free magnetic layer can be fluctuated by the field.
[0038] Moreover, said ferromagnetic layer may be monolayer structure which consists of CoFeCr or CoFe.
[0039] Moreover, it is desirable that the magnetic field which becomes the side which touches said non-magnetic layer at least from a NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) exists in said free magnetic layer. Thereby, magnitude of the layer joint field between said free magnetic layers and said ferromagnetic layers can be moderately made small.
[0040] Moreover, it is desirable that the magnetic field which becomes said free magnetic layer from the ferromagnetic ingredient which contains Co (cobalt) in the side which touches said non-magnetic material layer exists. Diffusion of the ingredients (nickel etc.) of said free magnetic layer to said non-magnetic material layer which touches said free magnetic layer can be prevented by this, and decline in magnetic-reluctance rate of change can be prevented.
[0041] Moreover, it is desirable that the ferromagnetic ingredient containing said Co is CoFe or CoFeCr.
[0042] In addition, if it is the magnetic sensing element which has the structure of this invention, it is possible to make regeneration efficiency eta (%) 50% or less at 10% or more. In addition, regeneration efficiency eta is defined as eta={(maximum resistance variation of magnetic sensing element by leak field from record medium)/(theoretical value of maximum resistance variation of magnetic sensing element)} x100. In addition, the theoretical value of the maximum resistance variation of a magnetic sensing element is the difference of resistance in case the magnetization direction of resistance in case the magnetization direction of a free magnetic layer and a fixed magnetic layer is in an anti-parallel condition, a free magnetic layer, and a fixed magnetic layer is in an parallel condition.
[0043] In the magnetic sensing element of this invention, an external magnetic field is impressed and 12 degrees or more can incline to the magnetization direction when the external magnetic field is not sometimes impressed for the magnetization direction of the width-of-recording-track field of said free magnetic layer.
[0044] By this invention, the laminating of said multilayers shall be carried out from the bottom in the sequence of said 1st antiferromagnetism layer, said fixed magnetic layer, said non-magnetic material layer, said free magnetic layer, said non-magnetic layer, said ferromagnetic layer, and said 2nd antiferromagnetism layer.
[0045] Or it is good also as that by which the laminating is carried out from the bottom in said multilayers in the sequence of said 2nd antiferromagnetism layer, said ferromagnetic layer, said non-magnetic layer, said free magnetic layer, said non-magnetic material layer, said fixed magnetic layer, and said 1st antiferromagnetism layer.
[0046] Moreover, in said free magnetic layer in this invention, a part of direction of thickness of said free magnetic layer may have the truck cross direction dimension of a truck width method, and the remaining part may have a larger truck cross direction dimension than a truck width method.
[0047] The anti-field inside the free magnetic layer resulting from the surface magnetic charge produced at the both-sides edge of said free magnetic layer as it is what has a truck cross direction dimension with said a part of larger free magnetic layer than a truck width method can be made small, and turbulence of the magnetization direction inside said free magnetic layer can be reduced.
[0048] It is easy to form so that it may have a truck cross direction dimension with said a part of larger free magnetic layer than a truck width method especially as a magnetic sensing element is the CPP (Current Perpendicular to the Plane) mold with which a current is supplied to the film surface and perpendicular direction of

said multilayers and it is the magnetic sensing element of the top mold which has said non-magnetic material layer, a fixed magnetic layer, and the 1st antiferromagnetism layer in the upper layer of said free magnetic layer.

[0049] Moreover, the laminating of two or more ferromagnetic ingredient layers from which the magnitude of the magnetic moment per unit area differs is carried out through a nonmagnetic interlayer, and said free magnetic layer can carry out thinly the magnetic moment per substantial unit area of said free magnetic layer to it being in the ferrimagnetism condition that the magnetization direction of said ferromagnetic ingredient layer which adjoins through said nonmagnetic interlayer serves as anti-parallel, and can raise the rate of change to the external magnetic field of the magnetization direction of said free magnetic layer. That is, since the field detection sensitivity of a magnetic sensing element improves, it is desirable. Moreover, the anti-field inside said free magnetic layer can be lessened.

[0050] As for said nonmagnetic interlayer, it is desirable to be formed with one sort or two sorts or more of alloys among Ru, Rh, Ir, Cr, Re, and Cu.

[0051] In addition, it is desirable to form at least one layer of said two or more ferromagnetic ingredient layers in this invention with the magnetic material which has the following presentations.

[0052] It is the magnetic material whose remaining presentation ratios an empirical formula is shown by CoFeNi, the presentation ratio of Fe is below 17 atom % more than 9 atom %, the presentation ratio of nickel is below 10 atom % more than 0.5 atom %, and are Co(es).

[0053] Moreover, it is desirable to form the interlayer who consists of a CoFe alloy or Co between said ferromagnetic ingredient layer by which the laminating was carried out to the location nearest to said non-magnetic material layer, and said non-magnetic material layer. When forming said interlayer, it is desirable to form at least one layer of said two or more ferromagnetic ingredient layers with the magnetic material which has the following presentations.

[0054] It is the magnetic material whose remaining presentation ratios an empirical formula is shown by CoFeNi, the presentation ratio of Fe is below 15 atom % more than 7 atom %, the presentation ratio of nickel is below 15 atom % more than pentatomic %, and are Co(es).

[0055] Furthermore, it is desirable to form all the layers of two or more of said ferromagnetic ingredient layers by said CoFeNi in this invention.

[0056] Two or more ferromagnetic ingredient layers from which the magnitude of the magnetic moment per unit area differs [a free magnetic layer] When it is in the artificial ferrimagnetism condition that the magnetization direction of said ferromagnetic ingredient layer which a laminating is carried out through a nonmagnetic interlayer and adjoins through said nonmagnetic interlayer serves as anti-parallel, In order to keep this anti-parallel magnetization condition suitable, there is the need of enlarging the switched connection field in the RKKY interaction which improves the quality of the material of said free magnetic layer, and is committed among said two or more ferromagnetic ingredient layers.

[0057] A NiFe alloy is one of those which are often used as a magnetic material which forms said ferromagnetic ingredient layer. Since a NiFe alloy was excellent in soft magnetic characteristics, it was used for the free magnetic layer etc. from the former, but when said free magnetic layer is made into laminating ferry structure, the anti-parallel bonding strength between the ferromagnetic ingredient layers formed with the NiFe alloy is not so strong.

[0058] So, in this invention, in order to improve the quality of the material of said ferromagnetic ingredient layer and to strengthen the anti-parallel bonding strength between said two or more ferromagnetic ingredient layers, we decided to use a CoFeNi alloy for all layers at least much more preferably among said two or more ferromagnetic ingredient layers. The above-mentioned anti-parallel bonding strength can be strengthened by making Co contain.

[0059] Thereby, the switched connection field in the RKKY interaction generated among said two or more ferromagnetic ingredient layers can be strengthened. Specifically, it can enlarge even about 293 (kA/m), a field (Hsf), i.e., a spin FUROPPU field, in case an anti-parallel condition collapses.

[0060] Moreover, the magnetostriction of two or more of said ferromagnetic ingredient layers can be stored within the limits of -3x10-6 to 3x10-6 as it is above-mentioned presentation within the limits, and coercive force can be made small below 790 (A/m).

[0061] In addition, as for this invention, it is effective to apply to the magnetic sensing element of the CPP (Current Perpendicular tothe Plane) mold with which an up electrode layer is electrically connected to the top face of said multilayers, a lower electrode layer is electrically connected to the inferior surface of tongue of said multilayers, and a current is supplied to the film surface and perpendicular direction of said multilayers.

[0062] If said multilayers have a semimetal ferromagnetism Heusler alloy layer when it is the magnetic sensing element of a CPP mold, since it can control the ratio of the rise spin electron which flows the inside of said multilayers, and a down spin electron and magnetic-reluctance rate of change can be raised, it is desirable.

[0063] Moreover, if the NiFe layer with high soft magnetic characteristics is in contact with said semimetal ferromagnetism Heusler alloy layer when said semimetal ferromagnetism Heusler alloy layer is said a part of free magnetic layer, since magnetic-reluctance rate of change can be raised, it is desirable.

[0064] In addition, in this invention, said 1st antiferromagnetism layer and said 2nd antiferromagnetism layer can be formed with the antiferromagnetism ingredient which has the same presentation.
[0065] Said 1st antiferromagnetism layer and/or said 2nd antiferromagnetism layer Moreover, a PtMn alloy, Or it is a X-Mn (however, X is one-sort [any] or two sorts or more of elements of Pd, Ir, Rh, Ru, Os, nickel, and Fe) alloy, or is Pt-Mn-X' (however, X'). It is desirable to be formed with the alloy which are any one sort or two sorts or more of elements of Pd, Ir, Rh, Ru, Au, Ag, Os, Cr, nickel, Ar, Ne, Xe, and Kr.
[0066] Moreover, in this invention, as for said multilayers, the laminating of a ferromagnetic layer and said 2nd antiferromagnetism layer is carried out to said free magnetic layer top or bottom through said non-magnetic layer. You may be the magnetic sensing element which is the structure where the laminating of said 1 antiferromagnetism layer was carried out on said fixed magnetic layer and by which the fixed magnetic layer was formed at least in the both-sides end face of the truck cross direction of said free magnetic layer through the non-magnetic material layer, and the electrode layer was formed on said 1st antiferromagnetism layer.
[0067] In this invention, said free magnetic layer and a fixed magnetic layer are arranged side by side crosswise [truck], and the current from said electrode layer serves as a flow direction energized to said fixed magnetic layer through a free magnetic layer or a free magnetic layer through a fixed magnetic layer from the truck cross direction.

[0068] While being able to enlarge resistance variation (deltaR) and being able to aim at improvement in a playback output more effectively in the magnetic sensing element of the above-mentioned structure, improvement in resistance rate of change can be aimed at by narrow-ization of the width of recording track. By carrying out the laminating of a ferromagnetic layer and the 2nd antiferromagnetism layer to said free magnetic layer top or bottom through a non-magnetic layer, even if it is the structure which has furthermore arranged said free magnetic layer and the fixed magnetic layer side by side crosswise [truck], magnetization control of said free magnetic layer can be rationalized.
[0069] Moreover, the manufacture approach of the magnetic sensing element of this invention is characterized by having the following processes.
(a) The process which carries out a laminating to the order of a 2nd antiferromagnetism layer, ferromagnetic layer, non-magnetic layer, free magnetic layer, and non-magnetic material layer, a fixed magnetic layer, a middle antiferromagnetism layer, and a nonmagnetic protective layer from the bottom on a substrate, (b) The process which gives 1st annealing in a magnetic field, is made to generate a switched connection field between said 2nd antiferromagnetism layers and said ferromagnetic layers, and fixes magnetization of said ferromagnetic layer crosswise [truck], (c) The process which forms an up antiferromagnetism layer for said nonmagnetic protective layer all or the process deleted in part, and on the (d) aforementioned nonmagnetic protective layer or a middle antiferromagnetism layer, and forms the 1st antiferromagnetism layer which has said middle antiferromagnetism layer and said up antiferromagnetism layer, (e) Process which gives 2nd annealing in a magnetic field, is made to generate a switched connection field between said 1st antiferromagnetism layers and said fixed magnetic layers, and fixes magnetization of said fixed magnetic layer in the magnetization direction of said ferromagnetic layer, and the crossing direction.
[0070] In this invention, continuation membrane formation of from the 2nd antiferromagnetism layer to the nonmagnetic protective layer is carried out on the substrate in the aforementioned (a) process.
[0071] In this invention, said nonmagnetic protective layer consists of noble metals which cannot oxidize easily, and thickness does not become large by oxidation like Ta film conventionally used as a nonmagnetic protective layer.
[0072] Therefore, since sufficient antioxidizing effectiveness can be acquired even if it forms said nonmagnetic protective layer thinly, the ion milling of low energy can remove said nonmagnetic protective layer, and said middle antiferromagnetism layer formed in the bottom of said nonmagnetic protective layer can be appropriately protected from the damage by said ion milling.
[0073] Moreover, even if said noble-metals element etc. is spread inside a middle antiferromagnetism layer and an up antiferromagnetism layer by annealing etc., the property of an antiferromagnetism layer does not deteriorate. If Ta film currently used conventionally is diffused inside an antiferromagnetism layer compared with Ru etc., since it will be easy to degrade the property (function) of an antiferromagnetism layer, it is not desirable.
[0074] It is desirable to form said nonmagnetic protective layer in this invention at any one sort of Ru, Re, Pd, Os, Ir, Pt, Au, Rh, Cu, and the Cr or two sorts or more.
[0075] At the aforementioned (a) process, form said middle antiferromagnetism layer by 10A or more 50A or less, or moreover, more preferably If it forms by 30A or more 40A or less, it is avoidable for a switched connection field not to occur but to turn to the direction as the magnetization direction of said free magnetic layer where the magnetization direction of said fixed magnetic layer is the same between said middle antiferromagnetism layers and said fixed magnetic layers, by the 1st annealing in a magnetic field of the aforementioned (b) process.
[0076] In addition, although it stated previously that sufficient antioxidizing effectiveness can be acquired by this

invention even if it formed said nonmagnetic protective layer thinly, it is the aforementioned (a) process and, specifically, said nonmagnetic protective layer can be formed by 3A or more 10A or less.
[0077] Moreover, it is desirable to delete said nonmagnetic protective layer or to remove said all nonmagnetic protective layers until the thickness of said nonmagnetic protective layer becomes 3A or less at the aforementioned (c) process.
[0078] When said all nonmagnetic protective layers are removed at the aforementioned (c) process, said 1st antiferromagnetism layer will consist of only said middle antiferromagnetism layer and said up antiferromagnetism layer. However, when said all nonmagnetic protective layers are removed, the front face of said middle antiferromagnetism layer may be damaged by ion milling, and antiferromagnetism may fall.
[0079] In this invention, if said nonmagnetic protective layer is extent which remains 3A or less, even if said nonmagnetic protective layer remains between said middle antiferromagnetism layer and said up antiferromagnetism layer, said middle antiferromagnetism layer, said nonmagnetic protective layer, and said up antiferromagnetism layer can function as the 1st antiferromagnetism layers as one.
[0080]
[Embodiment of the Invention] Drawing 1 is the fragmentary sectional view which looked at the magnetic sensing element of the 1st operation gestalt in this invention from the opposed face side with a record medium.
[0081] The magnetic sensing element shown in drawing 1 is a GMR head for reproducing the external signal recorded on the record medium. The opposed face with a record medium is a flat surface perpendicular [to the film surface of the thin film which constitutes for example, a magnetic sensing element] and parallel to the magnetization direction when the external magnetic field of the free magnetic layer of a magnetic sensing element is not impressed. In drawing 1 , the opposed face with a record medium is a flat surface parallel to an X-Z flat surface.
[0082] In addition, when a magnetic sensing element is used for the magnetic head of a surfacing type, the opposed face with a record medium is the so-called ABS side.
[0083] Moreover, a magnetic sensing element is formed on the trailing end face of the slider formed for example, with alumina-titanium carbide (aluminum2O3-TiC). A slider is joined to the supporter material by stainless steel material etc. in which elastic deformation is possible by the opposed face [with a record medium], and reverse side side, and magnetic-head equipment is constituted.
[0084] In addition, the truck cross direction is the cross direction of the field where the magnetization direction is changed by the external magnetic field, for example, is, the magnetization direction of illustration X, i.e., direction, of [when the external magnetic field of a free magnetic layer is not impressed].
[0085] In addition, the record medium has countered the opposed face with the record medium of a magnetic sensing element, and moves to an illustration Z direction. The direction of a leak field from this record medium is the direction of illustration Y.
[0086] In drawing 1, an alumina layer (not shown) is minded on the trailing end face of a slider. The lower shielding layer 20 which makes a lower electrode layer serve a double purpose is formed. On the lower shielding layer 20 The free magnetic layer 26 which consists of the ferromagnetic layer 24 which consists of the substrate layer 21, the seed layer 22, the 2nd antiferromagnetism layer 23, 1st a little more than magnetic layer 24a, and 2nd a little more than magnetic layer 24b, a non-magnetic layer 25, 1st magnetic layer 26a, and 2nd magnetic layer 26b, the non-magnetic material layer 27, 2nd fixed magnetic layer 28a, The multilayers A by which the laminating of nonmagnetic middle class 28b, the fixed magnetic layer 28 of the synthetic ferry PINDO mold which consists of 1st fixed magnetic layer 28c, the 1st antiferromagnetism layer 29, and the protective layer 30 was carried out to order from the bottom are formed.
[0087] The protective layer 30 of Multilayers A to a part of direction of thickness of 1st magnetic layer 26a of the free magnetic layer 26 has the truck cross direction dimension of the truck width method Tw, and the truck cross direction dimension of the ferromagnetic layer 24 from the remaining part of 1st magnetic layer 26a, the 2nd antiferromagnetism layer 23, the seed layer 22, and the substrate layer 21 is larger than the truck width method Tw to it.
[0088] Moreover, insulating layers 32 and 32 are formed in the truck cross direction both-sides section from a protective layer 30 to the middle of 1st magnetic layer 26a of the free magnetic layer 26, and the up shielding layer 31 which makes an up electrode layer serve a double purpose is formed on insulating layers 32 and 32 and the protective layer 30 of Multilayers A.
[0089] From the lower shielding layer 20 to the up shielding layer 31 is the magnetic sensing element of the gestalt of operation of the 1st of this invention.
[0090] Although the lower shielding layer 20 makes a lower electrode layer serve a double purpose and the up shielding layer 31 is making the up electrode layer serve a double purpose in drawing 1 , a lower shielding layer, a lower electrode layer and an up shielding layer, and an up electrode layer may be different layers currently formed with an ingredient different, respectively.

[0091] The magnetic sensing element shown in drawing 1 is the so-called top type of spin bulb mold MAG sensing element.

[0092] The lower shielding layer 20, the substrate layer 21, the seed layer 22, the 2nd antiferromagnetism layer 23, the ferromagnetic layer 24, a non-magnetic layer 25, the free magnetic layer 26, the non-magnetic material layer 27, the fixed magnetic layer 28, the 1st antiferromagnetism layer 29, a protective layer 30, an insulating layer 32, and the up shielding layer 31 are formed of thin film formation processes, such as a spatter and vacuum deposition.

[0093] As a spatter, it can form, for example by spatters using the preexisting sputtering system, such as magnetron sputtering, RF2 pole spatter, RF3 pole spatter, an ion beam spatter, and an opposite target type spatter. moreover -- this invention -- everything but a spatter or vacuum deposition -- MBE (molecular-beam-epitaxy) -- law and ICB (ion cluster-beam) -- membrane formation processes, such as law, are usable.

[0094] The both-sides end faces [in / in the multilayers A which consist of substrate layers 21 described above as shown in drawing 1 on each class of a protective layer 30 / the truck cross direction (the direction of illustration X) from a protective layer 30 to a part of 1st magnetic layer 26a of the free magnetic layer 26] Aa and Aa are perpendicular continuation sides to the front face Ab of Multilayers A. However, as shown by the dotted lines Aa1 and Aa1 of drawing 1 , the both-sides end faces in the truck cross direction from a protective layer 30 to a part of 1st magnetic layer 26a of the free magnetic layer 26 may be the inclined planes Aa1 and Aa1 to the front face Ab of Multilayers A.

[0095] In addition, the optical width of recording track Tw of the magnetic sensing element of drawing 1 is decided with the truck cross direction dimension of the non-magnetic material layer 27. Especially in the magnetic sensing element of the gestalt of this operation, 0.1 micrometers or less of optical width of recording track Tw can be set to 0.06 micrometers or less, and it can respond to two or more 200 Gbit/in recording density.

[0096] The magnetic sensing element shown in drawing 1 is the so-called spin bulb mold MAG sensing element, the magnetization direction of the fixed magnetic layer 28 is fixed in the direction parallel to the direction of illustration Y proper, moreover, magnetization of the free magnetic layer 26 is arranged in the direction of illustration X proper, and orthogonality relation has magnetization of the fixed magnetic layer 28 and the free magnetic layer 26. The leak field from a record medium invades in the direction of illustration Y of a magnetic sensing element, magnetization of the free magnetic layer 26 is changed with sufficient sensibility, electric resistance changes by the relation between fluctuation of this magnetization direction, and the fixed magnetization direction of the fixed magnetic layer 28, and the leak field from a record medium is detected by the electrical-potential-difference change based on this electric resistance value change.

[0097] However, it is the angular relation of the magnetization direction of 2nd fixed magnetic layer 28a, and the magnetization direction of the free magnetic layer 26 which is directly contributed to an electric resistance value change (output), and it is desirable to lie at right angles in the condition that the condition and signal field which the detection current is energizing [such angular relation] are not impressed.

[0098] In addition, the record medium which counters an opposed face with the record medium of a magnetic sensing element moves to an illustration Z direction.

[0099] A protective layer 30 consists of conductive ingredients, such as Ta, and the thickness in the gestalt of this operation is 30A.

[0100] The lower shielding layer 20 and the up shielding layer 31 are formed using magnetic materials, such as NiFe. In addition, as for the lower shielding layer 20 and the up shielding layer 31, it is desirable that the easy axis has turned to the truck cross direction (the direction of illustration X). The lower shielding layer 20 and the up shielding layer 31 may be formed by electrolysis plating.

[0101] As for the substrate layer 21, it is desirable to be formed by at least one or more sorts in Ta, Hf, Nb, Zr, Ti, Mo, and W. A substrate layer is formed by the thickness of 50A or less extent. In addition, this substrate layer does not need to be formed. With the gestalt of this operation, the thickness of the substrate layer 21 is 30A.

[0102] The seed layer 22 is formed using NiFe, NiFeCr, Cr, etc. With the gestalt of this operation, the thickness of the seed layer 22 is 50A.

[0103] In addition, since the magnetic sensing element in this operation is a CPP mold with which a sense current flows to the film surface and perpendicular direction of each class, it has the need that a sense current flows suitable also for a seed layer. Therefore, as for a seed layer, it is desirable that it is not the high quality of the material of specific resistance. That is, as for a seed layer, in a CPP mold, it is desirable to be formed with the low quality of the material of specific resistance, such as a NiFe alloy and Cr. In addition, a seed layer does not need to be formed.

[0104] The 2nd antiferromagnetism layer 23 and the 1st antiferromagnetism layer 29 A PtMn alloy, Or it is a X-Mn (however, X is one-sort [any] or two sorts or more of elements of Pd, Ir, Rh, Ru, Os, nickel, and Fe) alloy, or is Pt-Mn-X' (however, X'). It forms with the alloy which is any 1 or two or more sorts of elements of Pd, Ir, Rh, Ru, Au, Ag, Os, Cr, nickel, Ar, Ne, Xe, and Kr.

[0105] With the gestalt of this operation, the 1st antiferromagnetism layer 29 and the 2nd antiferromagnetism layer

23 can be formed using the antiferromagnetism ingredient which has the same presentation.
[0106] In the condition immediately after membrane formation, although these alloys are the face centered cubic structures (fcc) of an irregular system, they carry out a structure transformation by heat treatment at the face-centered square structure (fct) of a CuAuI type rule mold.
[0107] The thickness of the 2nd antiferromagnetism layer 23 is 80A - 300A, for example, 150A. In the alloy shown here by said PtMn alloy for forming an antiferromagnetism layer, and the formula of said X-Mn, it is desirable that the range of Pt or X is 37 - 63at%. Moreover, in the alloy shown by said PtMn alloy and the formula of said X-Mn, it is more desirable that the range of Pt or X is 47 - 57at%. Unless it specifies especially, the upper limit and minimum of the numerical range shown by - mean the above hereafter.
[0108] Moreover, in the alloy shown by the formula of Pt-Mn-X', it is desirable that the range of X'+Pt is 37 - 63at%. Moreover, in the alloy shown by the formula of said Pt-Mn-X', it is more desirable that the range of X'+Pt is 47 - 57at%. Furthermore, in the alloy shown by the formula of said Pt-Mn-X', it is desirable that the range of X' is 0.2 - 10at%. However, when X' is any one sort or two sorts or more of elements of Pd, Ir, Rh, Ru, Os, nickel, and Fe, as for X', it is desirable that it is the range of 0.2 - 40at%.
[0109] The antiferromagnetism layer which generates a big switched connection field can be obtained by using these alloys and heat-treating this. Especially, if it is a PtMn alloy, it has a switched connection field exceeding 48 or more kA/m, for example, 64 kA/m, and the blocking temperature which loses said switched connection field can obtain 380 degrees C, the outstanding, very high 2nd antiferromagnetism layer 23, and the 1st antiferromagnetism layer 29.
[0110] In addition, when the magnetic sensing element of drawing 1 is formed using the manufacture approach of the magnetic sensing element of the gestalt this operation explained later, it has the multilayer structure which the 1st antiferromagnetism layer 29 becomes from nonmagnetic protective layer 29b and up antiferromagnetism layer 29c which are set to middle antiferromagnetism layer 29a of 10A or more thickness 50A or less from the noble metals of 1A or more thickness 3A or less etc.
[0111] Middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c are an above-mentioned PtMn alloy and a X-Mn alloy, or are formed in the same antiferromagnetism ingredient of a presentation, and a concrete target using a Pt-Mn-X' alloy.
[0112] The comprehensive thickness which doubled the thickness of middle antiferromagnetism layer 29a and the thickness of up antiferromagnetism layer 29c is 80A or more 500A or less. For example, it is 150A. Since thickness is as thin as 10A or more 50A or less, if middle antiferromagnetism layer 29a is independent, it does not show antiferromagnetism, but it comes to show antiferromagnetism only after middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c are united, and produces a switched connection field between the fixed magnetic layers 28.
[0113] Moreover, since nonmagnetic protective layer 29b is thin 1A or more thickness 3A or less and it is formed by any one sort of Ru, Re, Pd, Os, Ir, Pt, Au, Rh, Cu, and the Cr, or two sorts or more Middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c are made to produce an antiferromagnetism-interaction, and it becomes possible to operate middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c as an antiferromagnetism layer of one. Moreover, even if the ingredient of nonmagnetic protective layer 29b is spread in middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c, the property of antiferromagnetism does not deteriorate.
[0114] In addition, nonmagnetic protective layer 29b may not exist, but the 1st antiferromagnetism layer 29 may consist of middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c. Moreover, the 1st antiferromagnetism layer 29 may be an antiferromagnetism layer of a monolayer.
[0115] As for 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a, it is desirable for it to be formed with a ferromagnetic ingredient, and to be formed with a NiFe alloy, Co, a CoFeNi alloy, a CoFe alloy, a CoNi alloy, etc., for example, to be formed especially of a CoFe alloy or Co. Moreover, as for 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a, being formed with the same ingredient is desirable.
[0116] Moreover, nonmagnetic interlayer 28b is formed of a non-magnetic material, and is formed among Ru, Rh, Ir, Cr, Re, and Cu with one sort or these two sorts or more of alloys. Being formed especially of Ru is desirable.
[0117] 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a are formed by about 10-70A, respectively. For example, the thickness of 1st fixed magnetic layer 28c is 30A, and the thickness of 2nd fixed magnetic layer 28a is 40A. Moreover, a nonmagnetic interlayer's thickness is formed by 3A - about 10A, for example, 8A.
[0118] In drawing 1 , that to which the laminating of 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a from which the magnetic moment per unit area (Msxt; product of saturation magnetic flux density and thickness) differs was carried out through nonmagnetic interlayer 28b functions as one fixed magnetic layer.
[0119] By forming 1st fixed magnetic layer 28c in contact with the 1st antiferromagnetism layer 29, and giving annealing in a magnetic field, the exchange anisotropy field (switched connection field) by switched connection arises in the interface of 1st fixed magnetic layer 28c and the 1st antiferromagnetism layer 29, and the

magnetization direction of 1st fixed magnetic layer 28c is fixed in the direction of illustration Y. When the magnetization direction of 1st fixed magnetic layer 28c is fixed in the direction of illustration Y, the magnetization direction of 2nd fixed magnetic layer 28a which counters through nonmagnetic interlayer 28b is fixed in the magnetization direction of 1st fixed magnetic layer 28c, and the condition of anti-parallel.

[0120] Thus, since 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a fix the magnetization direction of another side mutually and suit when the magnetization direction of 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a is in the ferrimagnetism condition used as anti-parallel, the magnetization direction of a fixed magnetic layer is powerfully fixable in the fixed direction as a whole.

[0121] In addition, the direction of the magnetic moment (Msxt) per [which added the magnetic moment (Msxt) per unit area of 1st fixed magnetic layer 28c and the magnetic moment (Msxt) per unit area of 2nd fixed magnetic layer 28a] composite unit area turns into the magnetization direction of a fixed magnetic layer.

[0122] In drawing 1 , the magnetic moment (Msxt) per each unit area is changed by forming 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a using the same ingredient, and changing each thickness further.

[0123] Moreover, the anti-field (dipole field) by fixed magnetization of 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a is cancellable when static magnetic field association of 1st fixed magnetic layer 28c and 2nd fixed magnetic layer 28a negates each other mutually. Thereby, the contribution to the fluctuation magnetization of the free magnetic layer 26 from the anti-field (dipole field) by fixed magnetization of the fixed magnetic layer 28 can be decreased.

[0124] Therefore, it becomes easier to amend the direction of fluctuation magnetization of the free magnetic layer 26 towards desired, and it becomes possible to obtain the spin bulb mold MAG sensing element which was excellent in symmetry with small asymmetry.

[0125] Here, when asymmetry shows the asymmetric degree of a playback output wave and a playback output wave is given, asymmetry will become small if the wave is symmetrical. Therefore, the playback output wave will be excellent in symmetric property, so that asymmetry approaches 0.

[0126] Said asymmetry is set to 0 when the direction of magnetization of the free magnetic layer 26 and the direction of fixed magnetization of the fixed magnetic layer 28 lie at right angles. If asymmetry shifts greatly, reading of the information from media will become impossible correctly, and will cause an error. For this reason, the dependability of regenerative-signal processing will improve as a thing with said small asymmetry, and it becomes what was excellent as a spin bulb mold MAG sensing element.

[0127] Moreover, although the anti-field (dipole field) Hd by fixed magnetization of the fixed magnetic layer 28 has uneven distribution that it is large and small in the center section, at the edge in the component height direction of the free magnetic layer 26 and single domain-ization in the free magnetic layer 26 may be barred It can prevent that can make the dipole field Hd small, and a magnetic domain wall is made in a free magnetic layer by this, the ununiformity of magnetization occurs, and a Barkhausen noise etc. occurs by making the fixed magnetic layer 28 into the above-mentioned laminated structure.

[0128] In addition, the fixed magnetic layer 28 may be formed with the two-layer structure of diffusion prevention layers, such as a layer and Co layer, which consists of 1 layer structure which used one of the above-mentioned magnetic materials, or one of the above-mentioned magnetic materials.

[0129] The non-magnetic material layer 27 is a layer which prevents magnetic association with the fixed magnetic layer 28 and the free magnetic layer 26, and it is desirable to be formed of the non-magnetic material which has conductivity, such as Cu, Cr, Au, and Ag. Being formed especially of Cu is desirable. The non-magnetic material layer 27 is formed by about 18-30A thickness. With the gestalt of this operation, the thickness of the non-magnetic material layer 27 is 30A.

[0130] Although the non-magnetic material layer 27 may be formed by insulating materials, such as aluminum 2O3 and SiO2, like the gestalt of this operation moreover, in the case of the magnetic sensing element of a CPP mold It is necessary to make thin thickness of the non-magnetic material layer 27, to form it also in the non-magnetic material layer 27 interior at 50A or less, when the non-magnetic material layer 27 is an insulating material, since it must be made for a sense current to have to flow to a film surface and a perpendicular direction, and to make it tunnel current flow. Moreover, when the non-magnetic material layer 27 is formed with the ingredient which contains partially an insulating material like 2Oaluminum 2O3, and TaO2 or Cu-aluminum 3 bipolar membrane, the non-magnetic material layer 27 can also be operated as a current-limiting layer which reduces an effectual component area.

[0131] In the magnetic sensing element shown in drawing 1 , the free magnetic layer 26 is the two-layer structure of 1st magnetic layer 26a and 2nd magnetic layer 26b.

[0132] 1st magnetic layer 26a of the side which touches a non-magnetic layer 25 They are a NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt). 2nd magnetic layer 26b of the side which touches the non-magnetic material layer 27 is the layer which consists of a ferromagnetic ingredient containing Co(es) (cobalt), such as Co,

CoFe, and CoFeNi. With the gestalt of this operation, the thickness of 1st magnetic layer 26a is 100A, and the thickness of 2nd magnetic layer 26b is 20A. It is desirable to choose CoFe and CoFeCr as the ferromagnetic ingredient containing Co.

[0133] By forming 2nd magnetic layer 26b of the free magnetic layer 26 in the layer which consists of a ferromagnetic ingredient containing Co (cobalt), diffusion of the ingredients (nickel etc.) of the free magnetic layer 26 to the non-magnetic material layer 27 can be prevented, and decline in magnetic-reluctance rate of change can be prevented.

[0134] In addition, the interface of 1st magnetic layer 26a and 2nd magnetic layer 26b which constitute the free magnetic layer 26 may be unable to be clearly grasped like a drawing. For example, it is the case where said 1st magnetic layer 26a and 2nd magnetic layer 26b cause thermal diffusion etc. In this case, said interface will not be carried out clearly. Therefore, the magnetism field which consists of a ferromagnetism ingredient layer which contains Co in the side which the magnetism field which becomes the side which touches the free magnetic layer 26 at least at a non-magnetic layer 25 when an interface with 1st magnetic layer 26a and 2nd magnetic layer 26b cannot be clearly grasped like the operation gestalt shown in drawing 1 from NiFe or NiFeX exists, and, on the other hand, touches the non-magnetic material layer 27 should just exist.

[0135] With the gestalt of this operation, the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out to the lower layer of width-of-recording-track field 26c of the free magnetic layer 26 through the non-magnetic layer 25.

[0136] The non-magnetic layer 25 is formed with one sort or two sorts or more of alloys among Ru, Rh, Ir, Cr, Re, and Cu. With the gestalt of this operation, the thickness of a non-magnetic layer 25 is 8A.

[0137] The ferromagnetic layer 24 is the two-layer structure of 1st a little more than magnetic layer 24a and 2nd a little more than magnetic layer 24b. With the gestalt of this operation, the thickness of 1st a little more than magnetic layer 24a is 8A, for example, and the thickness of 2nd a little more than magnetic layer 24b is 6A.

[0138] At drawing 1 , 2nd a little more than magnetic layer 24b which is the side which touches the non-magnetic layer 25 of the ferromagnetic layer 24 is formed by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt).

[0139] Moreover, 1st a little more than magnetic layer 24a which is the side which touches the 2nd antiferromagnetism layer 23 is formed with the ferromagnetic ingredient containing Co(es) (cobalt), such as Co and CoFe. By forming 1st a little more than magnetic layer 24a with the ferromagnetic ingredient containing Co (cobalt), the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 can be enlarged. It is desirable to choose CoFe and CoFeCr as the ferromagnetic ingredient containing Co.

[0140] In addition, also in the ferromagnetic layer 24, the magnetic field which becomes the side which touches a non-magnetic layer 25 at least from NiFe or NiFeX exists in said ferromagnetic layer 24, and, on the other hand, the magnetic field which consists of a ferromagnetic ingredient layer which contains Co in the side which touches the 2nd antiferromagnetism layer 23 should just exist in it. [as well as the free magnetic layer 26]

[0141] Or it is good also as monolayer structure which consists the ferromagnetic layer 24 of NiFe (permalloy) whose thickness is 3nm or less more greatly than 0nm.

[0142] Or said ferromagnetic layer 24 may be formed with the monolayer structure which consists of CoFeCr or CoFe.

[0143] According to the experimental result later mentioned also in which the above-mentioned monolayer structure, good reproducing characteristics can be acquired.

[0144] In the magnetic sensing element shown in drawing 1, the magnetization direction of the ferromagnetic layer 24 is turned in the direction which intersects the magnetization direction of the fixed magnetic layer 28 by the switched connection field with the 2nd antiferromagnetism layer 23.

[0145] Moreover, since the laminating of the free magnetic layer 26 which is a ferromagnetic ingredient layer which consists of a ferromagnetic ingredient is carried out to the ferromagnetic layer 24 through the non-magnetic layer 25, in this case, it is single-domain-ized by the RKKY interaction and the magnetization direction is turned in the layer joint field the free magnetic layer 26 minded the non-magnetic layer 25 with the ferromagnetic layer 24, and the magnetization direction of the fixed magnetic layer 28 and the crossing direction.

[0146] Thus, if single-domain-izing of the free magnetic layer 26 and control of the magnetization direction are performed by the layer joint field through the non-magnetic layer 25 with the ferromagnetic layer 24, the vertical bias field concerning the free magnetic layer 26 can control that turbulence and the magnetic-domain structure of the free magnetic layer 26 are disturbed by external magnetic fields, such as a leak field from a record medium.

[0147] Moreover, the thing in the ferrimagnetism condition that the magnetization direction of said ferromagnetic ingredient layer where the laminating of two or more ferromagnetic ingredient layers from which the magnitude of the magnetic moment per unit area differs is carried out through a nonmagnetic interlayer, and they adjoin through said nonmagnetic interlayer serves as anti-parallel is sufficient as the ferromagnetic layer 24. The magnetization

direction of the ferromagnetic layer 24 is firmly fixable to an one direction with this.
[0148] In addition, when changing into the artificial ferry condition of having formed the non-magnetic layer 25 by Ru, and having changed the 180 degrees of the magnetization directions of the free magnetic layer 26 and the ferromagnetic layer 24, it is desirable to make thickness of Ru into 8A - 11A or 15A - 21A.
[0149] After enlarging the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 and fixing the magnetization direction of the ferromagnetic layer 24 in the magnetization direction of the fixed magnetic layer 28, and the crossing direction strongly in this invention By making magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 smaller than said switched connection field the direction which single-domain-izes the free magnetic layer 26, and intersects the magnetization direction perpendicularly in the magnetization direction of the fixed magnetic layer 28 -- certain -- turning -- in addition -- and it is necessary to adjust so that it can leak and the magnetization direction of the free magnetic layer 26 can be fluctuated by the field
[0150] In order to enlarge the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 and to make magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 smaller than a switched connection field With the gestalt of this operation, magnitude (Msxt; product of saturation magnetic flux density and thickness) of the magnetic moment per unit area of the ferromagnetic layer 24 is made smaller than the magnitude (Msxt; product of saturation magnetic flux density and thickness) of the magnetic moment per unit area of the free magnetic layer 26.
[0151] In addition, the magnitude (Msxt; product of saturation magnetic flux density and thickness) of the magnetic moment per unit area of the ferromagnetic layer 24 is the sum of the magnitude (Msxt) of the magnetic moment per unit area of 1st a little more than magnetic layer 24a, and the magnitude (Msxt) of the magnetic moment per unit area of 2nd a little more than magnetic layer 24b. Moreover, the magnitude (Msxt; product of saturation magnetic flux density and thickness) of the magnetic moment per unit area of the free magnetic layer 26 is the sum of the magnitude (Msxt) of the magnetic moment per unit area of 1st magnetic layer 26a, and the magnitude (Msxt) of the magnetic moment per unit area of 2nd magnetic layer 26b.
[0152] Specifically, the ratio (Msxt of Msxt / ferromagnetic layer 24 of the free magnetic layer 26) of the magnitude (Msxt) of the magnetic moment per [to the magnitude (Msxt) of the magnetic moment per unit area of the ferromagnetic layer 24] unit area of the free magnetic layer 26 is made into 20 or less range or more by three.
[0153] Moreover, the ferromagnetic layer 24, 2nd a little more than magnetic layer 24b which is the side which touches a non-magnetic layer 25 By forming by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) Magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 is moderately made small.
[0154] Moreover, the free magnetic layer 26, 1st magnetic layer 26a which is the side which touches a non-magnetic layer 25 By forming by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) Magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 is moderately made small.
[0155] In the magnetic sensing element shown in drawing 1 , single-domain-izing of the free magnetic layer 26 and control of the magnetization direction will be adjusted in two steps, the magnitude of the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24, and the magnitude of the layer joint field between the ferromagnetic layer 24 and the free magnetic layer 26, and fine control can be performed easily.
[0156] Therefore, since single-domain-izing of the free magnetic layer 26 and control of the magnetization direction can be performed appropriately and easily, the further narrow track-ization of a magnetic sensing element can be promoted.
[0157] moreover, the direction which crosses the magnetization direction of the free magnetic layer 26 in the magnetization direction of the fixed magnetic layer 28 also with the structure where the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out to the lower layer of width-of-recording-track field 26c of the free magnetic layer 26 through a non-magnetic layer 25 -- certain -- turning -- in addition -- and it becomes possible to leak and to fluctuate the magnetization direction of the free magnetic layer 26 by the field.
[0158] Therefore, if it is a magnetic sensing element as shown in drawing 1 , it will be hard to be in the condition that the magnetization directions of the free magnetic layer 26 differ, at the center section and both ends of width-of-recording-track field 26c of the free magnetic layer 26.
[0159] In the magnetic sensing element of drawing 1 , the both-sides section from a protective layer 30 to the middle of 1st magnetic layer 26a of the free magnetic layer 26 is deleted, Multilayers A have the truck cross direction dimension of the truck width method Tw, and the truck cross direction dimension of the ferromagnetic layer 24 from the middle of 1st magnetic layer 26a, the 2nd antiferromagnetism layer 23, the seed layer 22, and the

substrate layer 21 is larger than the truck width method Tw.
[0160] The fragmentary sectional view and drawing 3 as which drawing 2 regarded the structure of the magnetic sensing element of the 2nd operation gestalt in this invention from the opposed face side with a record medium are the fragmentary sectional view which looked at the structure of the magnetic sensing element of the 3rd operation gestalt in this invention from the opposed face side with a record medium.
[0161] Unlike drawing 1 , with the operation gestalt shown in drawing 2 , the free magnetic layer 26 has a three-tiered structure which are 1st magnetic layer 26a, 2nd magnetic layer 26b, and 26d of middle magnetic layers. Except the configuration of this free magnetic layer 26, the magnetic sensing element of drawing 1 and the changing place are not.
[0162] 1st magnetic layer 26a which touches a non-magnetic layer 25 is formed by NiFe or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt), as drawing 1 explained. Or the magnetic field which becomes the side which touches said non-magnetic layer 25 from NiFe or NiFeX exists in said free magnetic layer 26.
[0163] Moreover, 2nd magnetic layer 26b which touches the non-magnetic material layer 27 is the magnetic material layer which contained Co as drawing 1 explained. Or the magnetic field which consists of a magnetic material which contained Co in the side which touches said non-magnetic material layer 27 exists in said free magnetic layer 26. There are CoFe, CoFeNi, CoFeCr, etc. in the magnetic material layer containing Co.
[0164] With this operation gestalt, 26d of middle magnetic layers pinched between said 1st magnetic layer 26a and 2nd magnetic layer 26b is prepared in order to adjust the magnetic moment (Msxt) per unit area of the free magnetic layer 26, and the quality of the material of 26d of said middle magnetic layers is determined from a viewpoint of the magnetic moment.
[0165] The quality of the material of 26d of said middle magnetic layers is a magnetic material layer containing NiFe, NiFeX, and Co. 1st magnetic layer 26a is nickel85at%Fe10at%Nb5at% as an example, 26d of middle magnetic layers is nickel80at%Fe20at%, and 2nd magnetic layer 26b is Co90at%Fe10at%.
[0166] in addition, a 1st magnetic layer 26a and 26d [of middle magnetic layers] interface and the interface with 26d of middle magnetic layers and 2nd magnetic layer 26b are clear by thermal diffusion etc., if sudden and it says by the example which there may not be, for example, was described above If the magnetic field which becomes the side which touches the non-magnetic layer 25 of the free magnetic layer 26 from NiFeNb exists, the magnetic field which becomes the side which touches the non-magnetic material layer 27 from CoFe exists and the magnetic field which consists of NiFe between them exists Said free magnetic layer 26 can be presumed to be what is formed by the three-tiered structure from the first.
[0167] In addition, said free magnetic layer 26 may be further constituted from three layers by the multilayer. The free magnetic layer 26 of drawing 3 is the monolayer structure of a ferromagnetic ingredient. As for said free magnetic layer 26, it is desirable to be formed by NiFe or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt). When said free magnetic layer 26 was formed with the monolayer structure of CoFe according to the experimental result mentioned later, it turned out that the playback sensibility eta is low, and a hysteresis gets worse, and it falls compared with the case where reproducing characteristics form said free magnetic layer 26 by NiFe or NiFeX.
[0168] Moreover, with the operation gestalt shown in drawing 3 , the ferromagnetic layer 24 is also monolayer structure. Said ferromagnetic layer 24 can be formed by NiFe, NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt), CoFe, CoFeCr, etc. In addition, in order to enlarge a switched connection field with the 2nd antiferromagnetism layer 23, as for the ferromagnetic layer 24 of monolayer structure, being formed with the ferromagnetic ingredient containing Co is desirable.
[0169] In addition, either may be monolayer structure among the ferromagnetic layer 24 and the free magnetic layer 26, and you may be the multilayer structure which another side becomes from a ferromagnetic ingredient.
[0170] In addition, in drawing 2 and drawing 3 , the ratio of the magnetic moment per [to the magnetic moment per unit area of the ferromagnetic layer 24] unit area of the free magnetic layer 26 etc. is the same as what was explained by drawing 1 R> 1.
[0171] Next, the multilayers of the magnetic sensing element of this invention may not carry out a configuration like the multilayers A from which the both-sides section was deleted to the middle of 1st magnetic layer 26a of the free magnetic layer 26 shown in drawing 1 .
[0172] In drawing 4 , it has the same laminated structure as the multilayers A of drawing 1 , and the fragmentary sectional view which looked at the magnetic sensing element of the 4th operation gestalt of this invention which has the multilayers C from which the both-sides sections B and B of the field of a truck width method are not deleted from the opposed face side with a record medium is shown.
[0173] In the magnetic sensing element of drawing 4 , lobe 20a and lobe 31a which are connected with Multilayers C, respectively are formed in the lower shielding layer 20 and the up shielding layer 31. The truck width method

Tw is decided in the smaller one among the truck cross direction dimensions of the connection 20a1 with the multilayers C of lobe 20a and lobe 31a, and a connection 31a1. The insulating layer 33 or insulating layer 34 which consists of an alumina etc. is formed in the both-sides section of lobe 20a and lobe 31a.
[0174] However, for the magnetic sensing element shown in drawing 4 , since the truck cross direction dimension of the fixed magnetic layer 28 and the free magnetic layer 26 is larger than the truck width method Tw, the so-called rate of side leading which detects an external magnetic field also in the part of the both-sides sections B and B of the field of the truck width method Tw becomes large, and the magnetic width of recording track is breadth and a cone.
[0175] Therefore, it is more desirable to delete Multilayers C at least, in the protective layer 30, the 1st antiferromagnetism layer 29, the fixed magnetic layer 28, and the non-magnetic material layer 27, so that the both-sides sections B and B may make alternate long and short dash lines L and L a side edge side.
[0176] However, if the both-sides sections B and B are deleted completely and removed to the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23, the free magnetic layer 26 will be single-domain-ized certainly, and it will become difficult to turn the magnetization direction in the direction which intersects the fixed magnetic layer 28. Moreover, if the both-sides sections B and B are completely removed to the free magnetic layer 26, since the anti-field of the truck cross direction of the free magnetic layer 26 will become large and magnetic-domain control of a free magnetic layer will become difficult, it is not desirable.
[0177] Therefore, as shown in drawing 1 , the structure where the both-sides section of Multilayers A was removed to a part of free magnetic layer 26 is a desirable gestalt.
[0178] It is the CPP (Current Perpendicular to thePlane) mold with which a current is supplied to the film surface and perpendicular direction of Multilayers A like the magnetic sensing element shown in drawing 1 . If the non-magnetic material layer 27, the fixed magnetic layer 28, and the 1st antiferromagnetism layer 29 are the magnetic sensing elements of the top mold in the upper layer of the free magnetic layer 26 A part of direction of thickness of the free magnetic layer 26 has the truck cross direction dimension of the truck width method Tw, and the remaining part tends to form the structure of having a larger truck cross direction dimension than the truck width method Tw.
[0179] The anti-field of the free magnetic layer 26 interior resulting from the surface magnetic charge produced at the both-sides edge of the free magnetic layer 26 as it is what has a truck cross direction dimension with a part of larger free magnetic layer 26 than the truck width method Tw can be made small, and turbulence of the magnetization direction of the free magnetic layer 26 interior can be reduced.
[0180] Drawing 5 is the fragmentary sectional view which looked at the magnetic sensing element of the 5th operation gestalt of this invention from the opposed face side with a record medium.
[0181] The magnetic sensing element of drawing 5 sequentially from the bottom instead of the multilayers A of drawing 1 The substrate layer 21, the seed layer 22, the 1st antiferromagnetism layer 29, 1st fixed magnetic layer 28c, Nonmagnetic interlayer 28b, The ferromagnetic layer 24 which consists of the free magnetic layer 26 which consists of the fixed magnetic layer 28 of the synthetic ferry PINDO mold which consists of 2nd fixed magnetic layer 28a, the non-magnetic material layer 27, 2nd magnetic layer 26b, and 1st magnetic layer 26a, a non-magnetic layer 25, 2nd a little more than magnetic layer 24b, and 1st a little more than magnetic layer 24a, It differs from the magnetic sensing element shown in drawing 1 with the point that the multilayers D by which the laminating of the 2nd antiferromagnetism layer 23 and the protective layer 30 was carried out to order from the bottom are formed. The magnetic sensing element shown in drawing 5 is the so-called bottom type of spin bulb mold MAG sensing element.
[0182] the ingredient with the same layer to which the same sign as drawing 1 was attached in drawing 5 -- it is formed by the same thickness.
[0183] However, unlike the magnetic sensing element of drawing 1 , the magnetic sensing element of drawing 5 may have the multilayer structure which the 2nd antiferromagnetism layer 23 becomes from nonmagnetic protective layer 23b and up antiferromagnetism layer 23c which are set to middle antiferromagnetism layer 23a of 10A or more thickness 50A or less from the noble metals of 1A or more thickness 3A or less etc.
[0184] Middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c are an above-mentioned PtMn alloy and a X-Mn alloy, or are formed in the same antiferromagnetism ingredient of a presentation, and a concrete target using a Pt-Mn-X' alloy.
[0185] The comprehensive thickness which doubled the thickness of middle antiferromagnetism layer 23a and the thickness of up antiferromagnetism layer 23c is 300A or less in 80A or more. For example, it is 150A. Since thickness is as thin as 10A or more 50A or less, if middle antiferromagnetism layer 23a is independent, it does not show antiferromagnetism, but it comes to show antiferromagnetism only after middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c are united, and produces a switched connection field between the ferromagnetic layers 24.
[0186] Moreover, since nonmagnetic protective layer 23b is thin 1A or more thickness 3A or less and it is formed by any one sort of Ru, Re, Pd, Os, Ir, Pt, Au, Rh, Cu, and the Cr, or two sorts or more Middle antiferromagnetism

layer 23a and up antiferromagnetism layer 23c are made to produce an antiferromagnetism-interaction, and it becomes possible to operate middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c as an antiferromagnetism layer of one. Moreover, even if the ingredient of nonmagnetic protective layer 23b is spread in middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c, the property of an antiferromagnetism layer does not deteriorate.
[0187] In addition, nonmagnetic protective layer 23b may not exist, but the 2nd antiferromagnetism layer 23 may consist of middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c. Moreover, the 2nd antiferromagnetism layer 23 may be an antiferromagnetism layer of a monolayer.
[0188] A part of the protective layer 30 of Multilayers D, the 2nd antiferromagnetism layer 23, the ferromagnetic layer 24, a non-magnetic layer 25, free magnetic layer 26, non-magnetic material layer 27, and 2nd fixed magnetic layer 28a have the truck cross direction dimension of the truck width method Tw. The truck cross direction dimension of nonmagnetic interlayer 28from the middle of 2nd fixed magnetic layer 28a b, 1st fixed magnetic layer 28c, the 1st antiferromagnetism layer 29, the seed layer 22, and the substrate layer 21 is larger than the truck width method Tw.
[0189] The both-sides end faces [in / in the magnetic sensing element shown in drawing 5 / the truck cross direction (the direction of illustration X) from a protective layer 30 to a part of 2nd fixed magnetic layer 28a] Da and Da are perpendicular continuation sides to the front face Db of Multilayers D. However, as shown by the dotted lines Da1 and Da1 of drawing 5 , the both-sides end face in the truck cross direction from a protective layer 30 to a part of 2nd fixed magnetic layer 28a may be an inclined plane to the front face Db of Multilayers D.
[0190] In addition, the optical width of recording track Tw of the magnetic sensing element of drawing 5 is decided with the truck cross direction dimension of the non-magnetic material layer 27. Especially in the magnetic sensing element of the gestalt of this operation, 0.1 micrometers or less of optical width of recording track Tw can be set to 0.06 micrometers or less, and it can respond to two or more 200 Gbit/in recording density.
[0191] Also by the magnetic sensing element shown in drawing 5 , the magnetization direction of the ferromagnetic layer 24 is turned in the direction which intersects the magnetization direction of the fixed magnetic layer 28 by the switched connection field with the 2nd antiferromagnetism layer 23.
[0192] Moreover, since the laminating of the free magnetic layer 26 is carried out to the ferromagnetic layer 24 through the non-magnetic layer 25, in this case, it is single-domain-ized by the RKKY interaction and the magnetization direction is turned in the layer joint field the free magnetic layer 26 minded the non-magnetic layer 25 with the ferromagnetic layer 24, and the magnetization direction of the fixed magnetic layer 28 and the crossing direction.
[0193] Thus, if single-domain-izing of the free magnetic layer 26 and control of the magnetization direction are performed by the layer joint field through the non-magnetic layer 25 with the ferromagnetic layer 24, the vertical bias field concerning the free magnetic layer 26 can control that turbulence and the magnetic-domain structure of the free magnetic layer 26 are disturbed by external magnetic fields, such as a leak field from a record medium.
[0194] Moreover, also by the magnetic sensing element shown in drawing 5 , single-domain-izing of the free magnetic layer 26 and control of the magnetization direction will be adjusted in two steps, the magnitude of the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24, and the magnitude of the layer joint field between the ferromagnetic layer 24 and the free magnetic layer 26, and fine control can be performed easily.
[0195] Therefore, since single-domain-izing of the free magnetic layer 26 and control of the magnetization direction can be performed appropriately and easily, the further narrow track-ization of a magnetic sensing element can be promoted.
[0196] moreover, the direction which crosses the magnetization direction of the free magnetic layer 26 in the magnetization direction of the fixed magnetic layer 28 also with the structure where the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out through a non-magnetic layer 25 on width-of-recording-track field 26c of the free magnetic layer 26 -- certain -- turning -- in addition -- and it becomes possible to leak and to fluctuate the magnetization direction of the free magnetic layer 26 by the field.
[0197] Therefore, if it is a magnetic sensing element as shown in drawing 5 , it will be hard to be in the condition that the magnetization directions of the free magnetic layer 26 differ, at the center section and both ends of width-of-recording-track field 26c of the free magnetic layer 26.
[0198] Moreover, since the 1st antiferromagnetism layer 29 and the fixed magnetic layer 28 are in a lower layer from the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 in the magnetic sensing element shown in drawing 5 , After generating an exchange anisotropy field strong between the 1st antiferromagnetism layer 29 and the fixed magnetic layer 28, when taking the manufacture approach of making the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 generating an exchange anisotropy field, it is easy to adjust the magnetization direction.
[0199] Drawing 6 is the fragmentary sectional view which looked at the magnetic sensing element of the 6th

operation gestalt of this invention from the opposed face side with a record medium.
[0200] Although the magnetic sensing element shown in drawing 6 is a magnetic sensing element of a top mold as well as the magnetic sensing element shown in drawing 1 The laminating of the 1st free magnetic layer 35 and the 2nd free magnetic layer 37 from which the magnitude of the magnetic moment per unit area differs [the free magnetic layer 38] is carried out through the nonmagnetic interlayer 36. the -- the [the 1 free magnetic layer 35 and] -- the magnetization direction of the 2 free magnetic layer 37 -- anti- -- it differs from the magnetic sensing element of drawing 1 at the point which is the so-called synthetic ferry free type of free magnetic layer which is in the ferrimagnetism condition which becomes parallel.
[0201] the ingredient with the same layer to which the same sign as drawing 1 was attached in drawing 6 -- since it is formed by the same thickness, explanation is omitted.
[0202] The 1st free magnetic layer 35 is the two-layer structure of 1st magnetic layer 35a and 2nd magnetic layer 35b. In addition, the free magnetic layer 35 may be a multilayer from two-layer, and a monolayer is sufficient as it.
[0203] 1st magnetic layer 35a of the side which touches a non-magnetic layer 25 They are a NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt). 2nd magnetic layer 35b of the side which touches the nonmagnetic interlayer 36 is the layer which consists of a ferromagnetic ingredient containing Co(es) (cobalt), such as Co, CoFe, and CoFeNi.
[0204] With the gestalt of this operation, the thickness of 1st magnetic layer 35a is 40A, and the thickness of 2nd magnetic layer 35b is 10A.
[0205] The nonmagnetic interlayer 36 is formed with one sort or two sorts or more of alloys among Ru, Rh, Ir, Cr, Re, and Cu. When forming the nonmagnetic middle class 36 by Ru and changing the free magnetic layer 38 into a synthetic ferry condition, it is desirable to make thickness of Ru into 8A - 11A.
[0206] The 2nd free magnetic layer 37 is a layer which consists of a ferromagnetic ingredient containing Co(es) (cobalt), such as Co, CoFe, and CoFeNi. The thickness of the 2nd free magnetic layer 37 is 80A.
[0207] the -- forming the 2 free magnetic layer 37 in the layer which consists of a ferromagnetic ingredient containing Co (cobalt) -- the [to the non-magnetic material layer 27] -- diffusion of the ingredient of the 2 free magnetic layer 37 can be prevented, and decline in magnetic-reluctance rate of change can be prevented. the [in addition,] -- the [the magnetic moment (Msxt) per unit area of the 1 free magnetic layer 35, and] -- the direction of the magnetic moment (Msxt) per [which added the magnetic moment (Msxt) per unit area of the 2 free magnetic layer 37] composite unit area turns into the magnetization direction of the free magnetic layer 38.
[0208] Also with the gestalt of this operation, the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out to the lower layer of width-of-recording-track field 38a of the free magnetic layer 38 through the non-magnetic layer 25.
[0209] in addition -- the gestalt of this operation -- the -- the [2nd magnetic layer 35b of the 1 free magnetic layer 35, and] -- it is desirable to form at least one layer in the 2 free magnetic layer 37 with the magnetic material which has the following presentations.
[0210] It is the magnetic material whose remaining presentation ratios an empirical formula is shown by CoFeNi, the presentation ratio of Fe is below 17 atom % more than 9 atom %, the presentation ratio of nickel is below 10 atom % more than 0.5 atom %, and are Co(es).
[0211] the [moreover,] -- the time of forming the interlayer who consists of a CoFe alloy or Co the 2 free magnetic layer 37, the non-magnetic material layer 27, and in between -- the -- the [2nd magnetic layer 35b of the 1 free magnetic layer 35, and] -- it is desirable to form at least one layer in the 2 free magnetic layer 37 with the magnetic material which has the following presentations.
[0212] It is the magnetic material whose remaining presentation ratios an empirical formula is shown by CoFeNi, the presentation ratio of Fe is below 15 atom % more than 7 atom %, the presentation ratio of nickel is below 15 atom % more than pentatomic %, and are Co(es).
[0213] Furthermore, it is desirable to form both the layers of 2nd magnetic layer 35b of the 1st free magnetic layer 35 and the 2nd free magnetic layer 37 in this invention by CoFeNi which has said presentation.
[0214] Thereby, the switched connection field in the RKKY interaction generated between 2nd magnetic layer 35b of the 1st free magnetic layer 35 and the 2nd free magnetic layer 37 can be strengthened. Specifically, it can enlarge even about 293 (kA/m), a field (Hsf), i.e., a spin FUROPPU field, in case an anti-parallel condition collapses.
[0215] moreover -- it is above-mentioned presentation within the limits -- the -- the [2nd magnetic layer 35b of the 1 free magnetic layer 35, and] -- the magnetostriction of the 2 free magnetic layer 37 can be stored within the limits of -3x10-6 to 3x10-6, and coercive force can be made small below 790 (A/m).
[0216] After enlarging the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 and fixing the magnetization direction of the ferromagnetic layer 24 in the magnetization direction of the fixed magnetic layer 28, and the crossing direction strongly also by the magnetic sensing element shown in drawing 6 By making magnitude of the layer joint field (RKKY interaction) through the non-magnetic

layer 25 between the 1st free magnetic layer 35 and the ferromagnetic layer 24 smaller than said switched connection field the -- the [the 1 free magnetic layer 35 and] -- the direction which single-domain-izes the 2 free magnetic layer 37, and intersects the magnetization direction perpendicularly in the magnetization direction of the fixed magnetic layer 28 -- certain -- turning -- in addition -- and it is necessary to adjust so that it can leak and the magnetization direction of the free magnetic layer 38 can be fluctuated by the field
[0217] the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 -- large -- carrying out -- the -- the gestalt of this operation in order to make magnitude of the layer joint field between the 1 free magnetic layer 35 and the ferromagnetic layer 24 smaller than said switched connection field -- the magnitude (Msxt) of the magnetic moment per unit area of the ferromagnetic layer 24 -- the -- it is made smaller than the magnitude (Msxt) of the magnetic moment per unit area of the 1 free magnetic layer 35.
[0218] Specifically, the ratio (the Msxt of Msxt / ferromagnetic layer 24 of 1 free magnetic layer) of the magnitude (Msxt) of the magnetic moment per [to the magnitude (Msxt) of the magnetic moment per unit area of the ferromagnetic layer 24] unit area of the 1st free magnetic layer 35 is made into 20 or less range or more by three. In addition, the magnitude of the magnetic moment per unit area of the 1st free magnetic layer 35 is the sum of the magnitude of the magnetic moment per unit area of 1st magnetic layer 35a, and the magnitude of the magnetic moment per unit area of 2nd magnetic layer 35b.
[0219] Moreover, the ferromagnetic layer 24, 2nd a little more than magnetic layer 24b which is the side which touches a non-magnetic layer 25 By forming by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) Magnitude of the layer joint field between the 1st free magnetic layer 35 and the ferromagnetic layer 24 is moderately made small.
[0220] Moreover, the 1st free magnetic layer 35, 1st magnetic layer 35a which is the side which touches a non-magnetic layer 25 By forming by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) Magnitude of the layer joint field between the 1st free magnetic layer 35 and the ferromagnetic layer 24 is moderately made small.
[0221] Also by the magnetic sensing element shown in drawing 6 , single-domain-izing of the free magnetic layer 38 and control of the magnetization direction will be adjusted in two steps, the magnitude of the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24, and the magnitude of the layer joint field between the ferromagnetic layer 24 and the 1st free magnetic layer 35, and fine control can be performed easily.
[0222] Therefore, since single-domain-izing of the free magnetic layer 38 and control of the magnetization direction can be performed appropriately and easily, the further narrow track-ization of a magnetic sensing element can be promoted.
[0223] moreover, the direction which crosses the magnetization direction of the free magnetic layer 38 in the magnetization direction of the fixed magnetic layer 28 also with the structure where the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out through a non-magnetic layer 25 on width-of-recording-track field 38a of the free magnetic layer 38 -- certain -- turning -- in addition -- and it becomes possible to leak and to fluctuate the magnetization direction of the free magnetic layer 38 by the field.
[0224] Therefore, if it is a magnetic sensing element as shown in drawing 6 , it will be hard to be in the condition that the magnetization directions of the free magnetic layer 38 differ, at the center section and both ends of width-of-recording-track field 38a of the free magnetic layer 38.
[0225] In the multilayers E by which the laminating of the substrate layer 21, the seed layer 22, the 2nd antiferromagnetism layer 23, the ferromagnetic layer 24, a non-magnetic layer 25, the free magnetic layer 38, the non-magnetic material layer 27, the fixed magnetic layer 28, the 1st antiferromagnetism layer 29, and the protective layer 30 was carried out to order from the bottom in the magnetic sensing element of drawing 6 The both-sides section from a protective layer 30 to the 2nd free magnetic layer 37 is deleted, and it has the truck cross direction dimension of the truck width method Tw. The truck cross direction dimension of the 1st free magnetic layer 35 from the nonmagnetic interlayer 36, the ferromagnetic layer 24, the 2nd antiferromagnetism layer 23, the seed layer 22, and the substrate layer 21 is larger than the truck width method Tw. Side leading which detects an external magnetic field on the outside of the field of the truck width method Tw of a magnetic sensing element can be reduced by this, and the vertical bias field (field of association between layers between the ferromagnetic layer 24 and the free magnetic layer 38) of still more sufficient magnitude for the free magnetic layer 38 can be supplied.
[0226] The both-sides end faces [in / in the magnetic sensing element shown in drawing 6 / the truck cross direction (the direction of illustration X) from the protective layer 30 to the nonmagnetic interlayer 36] Ea and Ea are perpendicular continuation sides to the front face Eb of Multilayers E. However, as shown by the dotted lines Ea1 and Ea1 of drawing 6 , the both-sides end face in the truck cross direction from the protective layer 30 to the nonmagnetic interlayer 36 may be an inclined plane to the front face Eb of Multilayers E.

[0227] In addition, the optical width of recording track Tw of the magnetic sensing element of drawing 6 is decided with the truck cross direction dimension of the non-magnetic material layer 27. Especially in the magnetic sensing element of the gestalt of this operation, 0.1 micrometers or less of optical width of recording track Tw can be set to 0.06 micrometers or less, and it can respond to two or more 200 Gbit/in recording density.

[0228] Drawing 7 is the fragmentary sectional view which looked at the magnetic sensing element of the 7th operation gestalt of this invention from the opposed face side with a record medium.

[0229] The magnetic sensing element of drawing 7 sequentially from the bottom instead of the multilayers E of drawing 6 The substrate layer 21, the seed layer 22, the 1st antiferromagnetism layer 29, 1st fixed magnetic layer 28c, Nonmagnetic interlayer 28b, The free magnetic layer 38 of the synthetic ferry free mold which consists of the fixed magnetic layer 28 of the synthetic ferry PINDO mold which consists of 2nd fixed magnetic layer 28a, the non-magnetic material layer 27, the 2nd free magnetic layer 37, the nonmagnetic middle class 36, and the 1st free magnetic layer 35, a non-magnetic layer 25, It differs from the magnetic sensing element shown in drawing 6 with the point that the multilayers F by which the laminating of the ferromagnetic layer 24 which consists of 2nd a little more than magnetic layer 24b and 1st a little more than magnetic layer 24a, the 2nd antiferromagnetism layer 23, and the protective layer 30 was carried out to order from the bottom are formed. The magnetic sensing element shown in drawing 6 is the so-called bottom type of spin bulb mold MAG sensing element.

[0230] The 1st free magnetic layer 35 is the two-layer structure of 1st magnetic layer 35a and 2nd magnetic layer 35b.

[0231] In drawing 7 , the layer to which the same sign as drawing 6 was attached is formed by the same ingredient and the same thickness.

[0232] However, unlike the magnetic sensing element of drawing 6 , the magnetic sensing element of drawing 7 may have the multilayer structure which the 2nd antiferromagnetism layer 23 becomes from nonmagnetic protective layer 23b and up antiferromagnetism layer 23c which are set to middle antiferromagnetism layer 23a of 10A or more thickness 50A or less from the noble metals of 1A or more thickness 3A or less etc.

[0233] Middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c are an above-mentioned PtMn alloy and a X-Mn alloy, or are formed in the same antiferromagnetism ingredient of a presentation, and a concrete target using a Pt-Mn-X' alloy.

[0234] The comprehensive thickness which doubled the thickness of middle antiferromagnetism layer 23a and the thickness of up antiferromagnetism layer 23c is 300A or less in 80A or more. For example, it is 150A. Since thickness is as thin as 10A or more 50A or less, if middle antiferromagnetism layer 23a is independent, it does not show antiferromagnetism, but it comes to show antiferromagnetism only after middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c are united, and produces a switched connection field between the ferromagnetic layers 24.

[0235] Moreover, since nonmagnetic protective layer 23b is thin 1A or more thickness 3A or less and it is formed by any one sort of Ru, Re, Pd, Os, Ir, Pt, Au, Rh, Cu, and the Cr, or two sorts or more Middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c are made to produce an antiferromagnetism-interaction, and it becomes possible to operate middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c as an antiferromagnetism layer of one. Moreover, even if the ingredient of nonmagnetic protective layer 23b is spread in middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c, the property of an antiferromagnetism layer does not deteriorate.

[0236] In addition, nonmagnetic protective layer 23b may not exist, but the 2nd antiferromagnetism layer 23 may consist of middle antiferromagnetism layer 23a and up antiferromagnetism layer 23c. Moreover, the 2nd antiferromagnetism layer 23 may be an antiferromagnetism layer of a monolayer.

[0237] In the magnetic sensing element shown in drawing 7 , two or more ferromagnetic ingredient layers (the [the 1 free magnetic layer 35,] 2 free magnetic layer 37) from which the magnitude of the magnetic moment per unit area differs are in a synthetic ferrimagnetism condition.

[0238] In the magnetic sensing element of drawing 7 , the both-sides section is deleted, a part of direction of thickness from the protective layer 30 of Multilayers F to 2nd fixed magnetic layer 28a has the truck cross direction dimension of the truck width method Tw, and the truck cross direction dimension from the remaining part of the 2nd fixed magnetic layer to the substrate layer 21 is larger than the truck width method Tw to it. Thereby, side leading which detects an external magnetic field on the outside of the field of the width of recording track Tw of a magnetic sensing element can be reduced.

[0239] The both-sides end faces [in / in the magnetic sensing element shown in drawing 7 / the truck cross direction (the direction of illustration X) from a protective layer 30 to 2nd fixed magnetic layer 28a] Fa and Fa are perpendicular continuation sides to the front face Fb of Multilayers F. However, as shown by the dotted lines Fa1 and Fa1 of drawing 7 , the both-sides end face in the truck cross direction from a protective layer 30 to 2nd fixed magnetic layer 28a may be an inclined plane to the front face Fb of Multilayers F.

[0240] In addition, the optical width of recording track Tw of the magnetic sensing element of drawing 7 is decided

with the truck cross direction dimension of the non-magnetic material layer 27. Especially in the magnetic sensing element of the gestalt of this operation, 0.1 micrometers or less of optical width of recording track Tw can be set to 0.06 micrometers or less, and it can respond to two or more 200 Gbit/in recording density.
[0241] Drawing 8 is the fragmentary sectional view which looked at the magnetic sensing element of the 8th operation gestalt of this invention from the opposed face side with a record medium.
[0242] The magnetic sensing element shown in drawing 8 differs from the magnetic sensing element shown in drawing 1 in that the semimetal ferromagnetism Heusler alloy layer 41 is formed between the non-magnetic material layer 27 and the free magnetic layer 26, and the semimetal ferromagnetism Heusler alloy layer 42 is formed between the fixed magnetic layer 28 and the non-magnetic material layer 27.
[0243] the ingredient with the same layer to which the same sign as drawing 1 was attached in drawing 8 -- it is formed by the same thickness.
[0244] The semimetal ferromagnetism Heusler alloy layers 41 and 42 are formed from NiMnSb (nickel manganese antimony), PtMnSb (platinum manganese antimony), PdMnSb (palladium manganese antimony), PtMnSn (platinum manganese tin), Co2MnSi, Co2MnGe, Co2MnSn, Co2MnAl, or one semimetal ferromagnetism Heusler alloy of Co2Mn1(AlxSi 100-x) 1 (however, x=0-100).
[0245] These semimetal ferromagnetism Heusler alloys are semimetals, Curie temperature is 200 degrees C or more, a room temperature (25 degrees C) shows ferromagnetism, and specific resistance is 50micro ohm-cm.
[0246] In the magnetic sensing element of a CPP mold, if it has the semimetal ferromagnetism Heusler alloy layers 41 and 42 as shown in drawing 8 , since it can control the ratio of the rise spin electron which flows the inside of Multilayers G, and a down spin electron and magnetic-reluctance variation deltaR can be raised, it is desirable.
[0247] Moreover, since the magnetization direction needs to change together with the free magnetic layer 26, when the NiFe layer with high soft magnetic characteristics is in contact with the semimetal ferromagnetism Heusler alloy layer 41, the semimetal ferromagnetism Heusler alloy layer 41 can raise magnetic-reluctance rate of change more, and is desirable.
[0248] The magnetic sensing element shown in drawing 8 from drawing 1 was a magnetic sensing element of the CPP mold with which a sense current is passed to the film surface perpendicular direction of Multilayers A, C, D, E, F, and G.
[0249] However, this invention is applicable also to the so-called CIP (CurrentIn the Plane) type of spin bulb mold MAG sensing element by which a sense current is passed to the film surface horizontal direction of the multilayers which have a fixed magnetic layer, a non-magnetic material layer, and a free magnetic layer.
[0250] Drawing 9 is the fragmentary sectional view which looked at the spin bulb mold MAG sensing element of a CIP mold from the opposed face side with a record medium as a gestalt of operation of the 9th of this invention.
[0251] The magnetic sensing element shown in drawing 9 has Multilayers A as well as the magnetic sensing element of drawing 1 . However, spacing of the truck width method Tw is opened in the top face Ab of Multilayers A, and it differs from the magnetic sensing element of drawing 1 in that the electrode layers 50 and 50 of a pair are formed. Therefore, in the magnetic sensing element of drawing 9 , a sense current flows to the film surface horizontal direction of Multilayers A. The electrode layers 50 and 50 are formed using W, Ta, Cr, Cu, Rh, Ir, Ru, Au, etc. as an ingredient. In addition, a sign 51 is a lower gap layer and a sign 52 is an up gap layer.
[0252] It is a spin bulb mold MAG sensing element, and the magnetization direction of the fixed magnetic layer 28 is fixed in the direction parallel to the direction of illustration Y proper, moreover, magnetization of a free magnetic layer is arranged in the direction of illustration X proper, and the magnetic sensing element of drawing 9 also has magnetization of a fixed magnetic layer and a free magnetic layer in orthogonality relation. The leak field from a record medium invades in the direction of illustration Y of a magnetic sensing element, magnetization of a free magnetic layer is changed with sufficient sensibility, electric resistance changes by the relation between fluctuation of this magnetization direction, and the fixed magnetization direction of a fixed magnetic layer, and the leak field from a record medium is detected by the electrical-potential-difference change based on this electric resistance value change.
[0253] However, it is the angular relation of the magnetization direction of 2nd fixed magnetic layer 28a, and the magnetization direction of the free magnetic layer 26 which is directly contributed to an electric resistance value change (output), and it is desirable to lie at right angles in the condition that the condition and signal field which the detection current is energizing [such angular relation] are not impressed.
[0254] In addition, the record medium which counters an opposed face with the record medium of a magnetic sensing element moves to an illustration Z direction.
[0255] Also by the magnetic sensing element shown in drawing 9 , single-domain-izing of the free magnetic layer 26 and control of the magnetization direction will be adjusted in two steps, the magnitude of the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24, and the magnitude of the layer joint field between the ferromagnetic layer 24 and the free magnetic layer 26, and fine control can be performed easily.

[0256] Therefore, since single-domain-izing of the free magnetic layer 26 and control of the magnetization direction can be performed appropriately and easily, the further narrow track-ization of a magnetic sensing element can be promoted.
[0257] moreover, the direction which crosses the magnetization direction of the free magnetic layer 26 in the magnetization direction of the fixed magnetic layer 28 also with the structure where the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out to the lower layer of width-of-recording-track field 26c of the free magnetic layer 26 through a non-magnetic layer 25 -- certain -- turning -- in addition -- and it becomes possible to leak and to fluctuate the magnetization direction of the free magnetic layer 26 by the field.
[0258] Therefore, if it is a magnetic sensing element as shown in drawing 1 , it will be hard to be in the condition that the magnetization directions of the free magnetic layer 26 differ, at the center section and both ends of width-of-recording-track field 26c of the free magnetic layer 26.
[0259] however, in order to raise magnetic-reluctance rate of change by the magnetic sensing element of a CIP mold Although it is desirable that the thickness of the free magnetic layer 26 is 30A - 40A, if thickness of the free magnetic layer 26 is made into this range The switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 is enlarged. After turning in the direction which fixes the magnetization direction of the ferromagnetic layer 24 in the magnetization direction of the fixed magnetic layer 28, and the crossing direction strongly, single-domain-izes the free magnetic layer 26, and intersects the magnetization direction perpendicularly in the magnetization direction of the fixed magnetic layer 28 certainly It becomes difficult to adjust so that it can leak and the magnetization direction of the free magnetic layer 26 can be fluctuated by the field (external magnetic field).
[0260] Moreover, when a sense current flows to the 2nd antiferromagnetism layer 23, the ferromagnetic layer 24, and a non-magnetic layer 25, splitting loss occurs.
[0261] Therefore, this invention acts more effectively [direction] applying to the magnetic sensing element of a CPP mold.
[0262] Drawing 10 is the top view which saw from above the free magnetic layer 26 of drawing 1 thru/or drawing 5 , and the magnetic sensing element shown in 8 and 9.
[0263] The arrow head in drawing shows the magnetization direction of the free magnetic layer 26 in the condition that the external magnetic field is not impressed to the magnetic sensing element.
[0264] In drawing 1 thru/or drawing 5 , and the magnetic sensing element shown in 8 and 9, a switched connection field with the 2nd antiferromagnetism layer 23 is strongly fixed in the magnetization direction of the fixed magnetic layer 28, and the crossing direction, and the magnetization direction of the ferromagnetic layer 24 is single-domain-ized by the layer joint field with the ferromagnetic layer 24 the free magnetic layer 26 minded the non-magnetic layer 25, and is turned in the direction in which the magnetization direction crosses in the magnetization direction of the fixed magnetic layer 28.
[0265] However, the magnetization direction of the free magnetic layer 26 is adjusted by extent which can be fluctuated by the leak field (external magnetic field) from a record medium. That is, an external magnetic field is impressed and only an include angle theta 1 or an include angle theta 2 moves to the magnetization direction when the external magnetic field is not sometimes impressed for the magnetization direction of the free magnetic layer 26. The sum of theta1 and theta2 is made to 12 degrees or more. Regeneration efficiency eta (%) can be made 10% or more for the sum of theta1 and theta2 to be 12 degrees or more.
[0266] In addition, regeneration efficiency eta (%) is defined as eta={(maximum resistance variation of magnetic sensing element by leak field from record medium)/(theoretical value of maximum resistance variation of magnetic sensing element)} x100. In addition, the theoretical value of the maximum resistance variation of a magnetic sensing element is the difference of resistance in case the magnetization direction of resistance in case the magnetization direction of a free magnetic layer and a fixed magnetic layer is in an anti-parallel condition, a free magnetic layer, and a fixed magnetic layer is in an parallel condition.
[0267] In addition, although the free magnetic layer 26 is two-layer structure which consists of 1st magnetic layer 26a and 2nd magnetic layer 26b, magnetization of 1st magnetic layer 26a and 2nd magnetic layer 26b turns to the always same direction.
[0268] moreover -- drawing 6 and 7 -- the free magnetic layer 38 -- the -- the [the 1 free magnetic layer 35 and] -- although it is laminating ferry structure with the 2 free magnetic layer 37 -- this case -- the [these] -- the [the 1 free magnetic layer 35 and] -- similarly magnetization fluctuation of the 2 free magnetic layer 37 can be considered to be magnetization fluctuation of the free magnetic layer 26 explained by drawing 10 R> 0. However, the magnetization direction of said 1st free magnetic layer 35 and 2nd free magnetic layer 37 is maintaining the anti-parallel condition.
[0269] Drawing 11 is the magnetic sensing element of the gestalt from which drawing 1 thru/or drawing 9 differ. The magnetic sensing element shown in drawing 11 is the fragmentary sectional view seen from the opposed face

side with a record medium. In addition, the layer of the same sign as the sign given to either drawing 1 thru/or drawing 9 expresses the same layer as them.

[0270] The fixed magnetic layer 28 is formed in the both sides of the truck cross direction (the direction of illustration X) of the free magnetic layer 60 through the non-magnetic material layer 27 at least, and, as for the magnetic sensing element shown in drawing 11 , the 1st antiferromagnetism layer 29 is formed on said fixed magnetic layer 28. The electrode layer 50 is formed on said 1st antiferromagnetism layer 29. Moreover, the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out to said free magnetic layer 60 bottom through the non-magnetic layer 25.

[0271] In the magnetic sensing element shown in drawing 11 , although the flow direction of a current is the same as the magnetic sensing element of the CIP mold explained by drawing 9 in order that the current from said electrode layer 50 may flow the fixed magnetic layer 28, the non-magnetic material layer 27, and the free magnetic layer 60 in the direction (the direction of illustration X) parallel to a film surface drawing 11 -- said current -- the order of the fixed magnetic layer 28-non-magnetic material layer 27-free magnetic layer 50 -- or in order to flow each class in that reverse order, this point is the same as the magnetic sensing element of the CPP mold explained by drawing 1 thru/or drawing 8 .

[0272] Although it is expected that the magnetic sensing element of the CPP mold explained by drawing 1 thru/or drawing 8 changes to the magnetic sensing element of a CIP mold as structure where it can respond by future high recording density-ization, if the fault of the magnetic sensing element of a CPP mold makes component size in a flat surface quite small and the total thickness is not thickened, it is a point that an output cannot be earned. On the other hand, the free magnetic layer 60 and the fixed magnetic layer 28 are put in order and arranged crosswise [truck] (the direction of illustration X) through the non-magnetic material layer 27 like the magnetic sensing element shown in drawing 11 . In case of the structure which carried out the laminating of the 1st antiferromagnetism layer 29 and the electrode layer 50 on said fixed magnetic layer 28 The above-mentioned component size and the above-mentioned total thickness become relation contrary to a CPP mold (namely, the "component size" said with a CPP mold corresponds to the size of the Y-Z flat surface of a direction parallel to the direction of thickness (illustration Z direction) in drawing 1111). Since it corresponds to the width method of the truck cross direction (the direction of illustration X) of the free magnetic layer 60 in drawing 11 , with the "total thickness" said with a CPP mold with the structure of drawing 11 It is possible to be able to thicken the "total thickness" which "plane component size" said with a CPP mold can be made small, and is said with a CPP mold, consequently to aim at improvement in a playback output. Moreover, resistance rate of change can be raised by narrow-ization of the width of recording track Tw.

[0273] Moreover, in the magnetic sensing element shown in drawing 11 , there is also an advantage that spacing of the shielding layers 20 and 31 in which the free magnetic layer 60 is formed up and down compared with the magnetic sensing element shown in drawing 1 thru/or drawing 9 , i.e., gap length, can be made small. Moreover, that the thickness H1 formed in the both-sides end face of the truck cross direction of the free magnetic layer 60 is thickly formed compared with the thickness H2 of the non-magnetic material layer 27 formed between the fixed magnetic layer 28 and the seed layer 22 can reduce the amount in which a current carries out splitting to the non-magnetic material layer 27 formed between said fixed magnetic layers 28 and seed layers 22, and said non-magnetic material layer 27 has it. [desirable] However, when an insulating layer 66 is formed in the bottom of the fixed magnetic layer 28 like the after-mentioned, since it does not generate in the non-magnetic material layer 27 on the seed layer 22, the need of the splitting loss of a current of taking the above-mentioned point into consideration is lost in it.

[0274] By the way, one of the troubles of the structure of the magnetic sensing element shown in drawing 11 is the point what to single-domain-ize the free magnetic layer 60, and to carry out magnetization control.

[0275] So, in the magnetic sensing element shown in drawing 11 , we decided to adopt the laminated structure of the non-magnetic layer 25 explained by drawing 1 R> 1 thru/or drawing 9 , the ferromagnetic layer 24, and the 2nd antiferromagnetism layer 23, namely, the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 was carried out to the free magnetic layer 60 bottom through the non-magnetic layer 25. It enabled this to perform appropriately and easily single-domain-izing and magnetization control of said free magnetic layer 60.

[0276] the magnetic sensing element shown in drawing 11 -- the truck cross direction (the direction of illustration X) of said free magnetic layer 60 -- since the fixed magnetic layer 28 should exist only in both sides at least, an insulating layer 66 may be buried to the height location of the arbitration of the 2nd antiferromagnetism layer 23, the ferromagnetic layer 24, and a non-magnetic layer 25, and the fixed magnetic layer 28 may be formed on it. The splitting loss of a current can be reduced by this.

[0277] Moreover, in the magnetic sensing element shown in drawing 11 , although said free magnetic layer 60 can choose various structures, such as monolayer structure, multilayer structure of a magnetic layer, or synthetic ferry structure, as arbitration, it has structure which carried out the laminating of two or more magnetic layers 61, 63, and 65 on both sides of the speculer layers (specular reflection layer) 62 and 64 between each class at drawing 11 . This

structure is employable by drawing 1 thru/or any magnetic sensing element of drawing 9 .
[0278] In the quality of the material of said speculer layers 62 and 64, Fe-O, nickel-O, Co-O, Co-Fe-O, Co-Fe-nickel-O, aluminum-O, and aluminum-Q-O (here -- Q -- B --) One or more sorts chosen from Si, N, Ti, V, Cr, Mn, Fe, Co, and nickel, R-O (it Hf(s) here -- R -- Cu, Ti, V, Cr, Zr, Nb, and Mo --) one or more sorts of oxides chosen from Ta and W, aluminum-N, and aluminum-Q-N (here -- Q -- B --) One or more sorts chosen from Si, O, Ti, V, Cr, Mn, Fe, Co, and nickel, the nitride of R-N (one or more sorts as which R is chosen from Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, and W here), a semimetal whistler alloy, etc. can be shown.
[0279] For example, although said magnetic layers 61, 63, and 65 are formed with magnetic materials, such as CoFe, it is oxidizing the front face of these magnetic layers 61, 63, and 65 by the existing approach, and it becomes possible to form the speculer layers 62 and 64 in said front face. Or the speculer layers 62 and 64 may be formed by a spatter etc. between said magnetic layers.
[0280] The thickness of these speculer layers 62 and 64 is very thin, and each magnetic layers 61, 62, and 65 are single-domain-ized in the same direction by direct ferromagnetic association through ferromagnetic RKKY association through the speculer layers 62 and 64, the pinhole formed in said speculer layers 62 and 64, magnetostatic association (topology cull coupling or the Orange Peel coupling) by the interface granularity of said speculer layers 62 and 64, etc.
[0281] Compared with the magnetic layers 61 and 65 of the upper and lower sides, as for the magnetic layer 63 prepared right in the middle among each magnetic layers 61, 63, and 65, thickness is thick. Although magnetization may be fixed crosswise [truck] (the direction of illustration X) by the RKKY exchange interaction generated between the ferromagnetic layers 24, the magnetic layer 61 below said magnetic layer 63 The magnetic layer 63 of middle is in the condition of having been weakly single-domain-ized by extent which can carry out magnetization fluctuation of the thickness to external magnetization for a thick thing and the reason of not receiving a RKKY exchange interaction directly, and the magnetic layer 63 is functioning as a free magnetic layer 63 substantially. In addition, there may be a magnetic layer 65 above said magnetic layer 63, or there may be. [no]
[0282] In addition, the advantage which forms the speculer layers 62 and 64 in each magnetic layers 61, 63, and 65 For example, mean free path lambda+ of the conduction electron in which lengthening mean free path lambda+ of conduction electron with rise spin compared with the former therefore has said rise spin by becoming possible, It is the point of becoming possible to be able to enlarge a difference with mean free path lambda- of conduction electron with down spin, and to aim at improvement in a playback output with improvement in resistance rate of change (deltaR/R).
[0283] Moreover, a non-magnetic layer 25, the ferromagnetic layer 24, and the 2nd antiferromagnetism layer 23 may be formed in the free magnetic layer 60 bottom of drawing 11 . The manufacture approach of the magnetic sensing element shown in drawing 1 is explained.
[0284] First, after forming an alumina layer (not shown) on the substrate (wafer used as a slider) which is not illustrated, The free magnetic layer 26, the non-magnetic material layer 27 which consist of the ferromagnetic layer 24 which consists of the lower shielding layer 20 from the bottom, the substrate layer 21, the seed layer 22, the 2nd antiferromagnetism layer 23, 1st a little more than magnetic layer 24a, and 2nd a little more than magnetic layer 24b, a non-magnetic layer 25, 1st magnetic layer 26a, and 2nd magnetic layer 26b, 2nd fixed magnetic layer 28a, nonmagnetic middle class 28b, the fixed magnetic layer 28 of the synthetic ferry PINDO mold which consists of 1st fixed magnetic layer 28c, middle antiferromagnetism layer 29a, and nonmagnetic protective layer 29b are formed by the spatter.
[0285] As a spatter, it can form, for example by spatters using the preexisting sputtering system, such as magnetron sputtering, RF2 pole spatter, RF3 pole spatter, an ion beam spatter, and an opposite target type spatter. moreover -- this invention -- everything but a spatter or vacuum deposition -- MBE (molecular-beam-epitaxy) -- law and ICB (ion cluster-beam) -- membrane formation processes, such as law, are usable.
[0286] the ingredient with the same layer to which the same sign as drawing 1 was attached in drawing 12 -- it is formed by the same thickness.
[0287] In addition, middle antiferromagnetism layer 29a is a layer which constitutes the 1st antiferromagnetism layer 29 behind, and is formed with the ingredient of the same presentation as the 2nd antiferromagnetism layer 23.
[0288] Middle antiferromagnetism layer 29a specifically A PtMn alloy, Or it is a X-Mn (however, X is one-sort [any] or two sorts or more of elements of Pd, Ir, Rh, Ru, Os, nickel, and Fe) alloy, or is Pt-Mn-X' (however, X'). It forms with the alloy which is any 1 or two or more sorts of elements of Pd, Ir, Rh, Ru, Au, Ag, Os, Cr, nickel, Ar, Ne, Xe, and Kr.
[0289] Nonmagnetic protective layer 29b needs to be the precise layer which cannot oxidize easily due to atmospheric-air exposure. In this invention, nonmagnetic protective layer 29b is formed using the following ingredient. For example, it is desirable to form with the ingredient which consists of any one sort of Ru, Re, Pd, Os, Ir, Pt, Au, Rh, Cu, and the Cr or two sorts or more.
[0290] By carrying out spatter membrane formation using noble metals, such as Ru, etc., precise nonmagnetic

protective layer 29b which cannot oxidize easily due to atmospheric-air exposure can be obtained. Therefore, even if it makes thin thickness of nonmagnetic protective layer 29b, it can prevent appropriately that the fixed magnetic layer 28 oxidizes by atmospheric-air exposure.

[0291] It is desirable to form nonmagnetic protective layer 29b by 10A or less by 3A or more with this invention. It is forming by 8A or less by 3A or more more preferably. It is possible to prevent appropriately that middle antiferromagnetism layer 29a oxidizes by atmospheric-air exposure also by nonmagnetic protective layer 29b of thin thickness of this level.

[0292] Thus, by having formed nonmagnetic protective layer 29b by thin thickness, ion milling in the drawing 13 process can be performed by low energy, and milling control can be raised compared with the former. R> drawing 13 3 process explains this point in detail.

[0293] As shown in drawing 12 , after carrying out the laminating of each class from the lower shielding layer 20 to nonmagnetic protective layer 29b on a substrate, 1st annealing in a magnetic field is given. Impressing the 1st field in the width-of-recording-track Tw (direction of illustration X) direction, it heat-treats with the 1st heat treatment temperature, a switched connection field is generated between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24, and magnetization of the ferromagnetic layer 24 is fixed to the direction of illustration X, i.e., the truck cross direction. In the layer joint field committed between the magnetic layers 24 through a non-magnetic layer 25, and this case, the free magnetic layer 26 is single-domain-ized by the RKKY interaction, and, as for the direction of illustration X, the magnetization direction is turned to 180-degree opposite direction by it. In addition, 1st heat temperature is made into 270 degrees C, for example, and magnitude of a field is set to 800k (A/m). In addition, the magnitude of the 1st field is larger than the saturation field of the ferromagnetic layer 24 and the free magnetic layer 26.

[0294] The 2nd antiferromagnetism layer 23 A PtMn alloy, Or it is a X-Mn (however, X is one-sort [any] or two sorts or more of elements of Pd, Ir, Rh, Ru, Os, nickel, and Fe) alloy, or is Pt-Mn-X' (however, X'). It forms with the alloy which is any 1 or two or more sorts of elements of Pd, Ir, Rh, Ru, Au, Ag, Os, Cr, nickel, Ar, Ne, Xe, and Kr. In the condition immediately after membrane formation, although these alloys are the face centered cubic structures (fcc) of an irregular system, they carry out a structure transformation by heat treatment at the face-centered square structure (fct) of a CuAuI type rule mold. The thickness of the 2nd antiferromagnetism layer is 80A - 300A, for example, 150A.

[0295] In the alloy shown here by said PtMn alloy for forming an antiferromagnetism layer, and the formula of said X-Mn, it is desirable that the range of Pt or X is 37 - 63at%. Moreover, in the alloy shown by said PtMn alloy and the formula of said X-Mn, it is more desirable that the range of Pt or X is 47 - 57at%. Unless it specifies especially, the upper limit and minimum of the numerical range shown by - mean the above hereafter.

[0296] Moreover, in the alloy shown by the formula of Pt-Mn-X', it is desirable that the range of X'+Pt is 37 - 63at%. Moreover, in the alloy shown by the formula of said Pt-Mn-X', it is more desirable that the range of X'+Pt is 47 - 57at%. Furthermore, in the alloy shown by the formula of said Pt-Mn-X', it is desirable that the range of X' is 0.2 - 10at%. However, when X' is any one sort or two sorts or more of elements of Pd, Ir, Rh, Ru, Os, nickel, and Fe, as for X', it is desirable that it is the range of 0.2 - 40at%.

[0297] The antiferromagnetism layer which generates a big switched connection field can be obtained by using these alloys and applying this to the 1st annealing in a magnetic field. Especially, if it is a PtMn alloy, it has a switched connection field exceeding 48 or more kA/m, for example, 64 kA/m, and the blocking temperature which loses said switched connection field can obtain 380 degrees C and the outstanding, very high 2nd antiferromagnetism layer 23.

[0298] In addition, middle antiferromagnetism layer 29a by which the laminating was carried out on the fixed magnetic layer 28 30A - 40A, since it is thin, and 10A - 50A, since [more desirable], and even if thickness does not show antiferromagnetism or shows antiferromagnetism, since it is very weak, in the 1st annealing in a magnetic field A switched connection field is not generated between 1st fixed magnetic layer 28c and middle antiferromagnetism layer 29a, and the magnetization direction of the fixed magnetic layer 28 is not fixed in the direction of illustration X.

[0299] Moreover, noble-metals elements, such as Ru which constitutes nonmagnetic protective layer 29b, etc. are considered to be spread inside middle antiferromagnetism layer 29a by the 1st above-mentioned annealing in a magnetic field. Therefore, the configuration element near the front face of middle antiferromagnetism layer 29a after heat treatment consists of elements, noble-metals elements, etc. which constitute middle antiferromagnetism layer 29a. Moreover, it is thought that there are more noble-metals elements diffused inside middle antiferromagnetism layer 29a the front-face side of middle antiferromagnetism layer 29a than the inferior-surface-of-tongue side of middle antiferromagnetism layer 29a, and presentation ratios, such as a diffused noble-metals element, decrease to an inferior surface of tongue gradually according to the other side from the front face of middle antiferromagnetism layer 29a.

[0300] Moreover, also as for between 1st magnetic layer 26a which constitutes the free magnetic layer 26 further,

and 2nd magnetic layer 26b, a presentation tends to cause thermal diffusion between 1st a little more than magnetic layer 24a which constitutes the ferromagnetic layer 24, and 2nd a little more than magnetic layer 24b.
[0301] The above-mentioned presentation modulation can be checked with the equipment which analyzes the chemical composition of thin films, such as a SIMS analysis apparatus.
[0302] Next, at the process shown in drawing 13 , nonmagnetic protective layer 29b is deleted by ion milling. or [that nonmagnetic protective layer 29b is left behind by 1A - 3A thickness] -- or all are removed.
[0303] The ion milling of low energy can be used at the ion milling process shown in drawing 13 . The reason is that nonmagnetic protective layer 29b is formed by the very thin thickness which is 3A - about 10A.
[0304] The ion milling of low energy is defined as beam voltage (acceleration voltage) being the ion milling using the ion beam below 1000V. For example, the beam voltage of 150V-500V is used. With the gestalt of this operation, the 200 argon (Ar) ion beam of low beam voltage of V is used.
[0305] On the other hand, if for example, Ta film is used for nonmagnetic protective layer 29b, since it will oxidize by this Ta film itself and atmospheric-air exposure, if it does not form by 30A - about 50A thick thickness, the layer under it cannot fully be protected from oxidation, but, moreover, as for Ta film, the volume will become large by oxidation, and the thickness of Ta film will swell to about 50A or more.
[0306] In order to remove Ta film of such thick thickness by ion milling, when it is necessary to remove Ta film by the ion milling of high energy and the ion milling of high energy is used, it is very difficult to carry out milling control so that only Ta film may be removed.
[0307] Therefore, middle antiferromagnetism layer 29a currently formed in the bottom of Ta film is also deleted deeply, the interior is entered from the front face of middle antiferromagnetism layer 29a which inert gas, such as Ar used for middle antiferromagnetism layer 29a at the time of ion milling, exposed, or the crystal structure of the surface part of middle antiferromagnetism layer 29a breaks, and a lattice defect occurs (the Mixing effectiveness). The magnetic properties of middle antiferromagnetism layer 29a tend to deteriorate by these damages. When Ta film which has thickness about 50A or more is shaved by the ion milling of low energy, the processing time becomes moreover, less practical [start too much and]. Moreover, compared with said noble metals etc., it is easy to carry out diffusion permeation of the Ta at middle antiferromagnetism layer 29a at the time of membrane formation, and even if it has shaved and removed only Ta film, Ta mixes it in the exposed middle antiferromagnetism layer 29a front face. As for middle antiferromagnetism layer 29a which Ta mixed, an antiferromagnetism property deteriorates.
[0308] On the other hand, in this invention, nonmagnetic protective layer 29b can be deleted by the ion milling of low energy. The ion milling of low energy has a late milling rate, and it becomes possible to narrow the margin of a milling stop location. It also becomes possible to stop milling at the moment of removing nonmagnetic protective layer 29b by ion milling especially. Middle antiferromagnetism layer 29a stops therefore, receiving a serious damage by ion milling. In addition, as for whenever [incident angle / of the ion milling in the drawing 13 process], it is desirable to make it from a normal 30 degrees - 70 degrees over a nonmagnetic protective layer 29b front face. Moreover, the processing time of ion milling is about 1 minute.
[0309] However, it is more desirable to leave nonmagnetic protective layer 29b by 1A - 3A thickness, since the front face of middle antiferromagnetism layer 29a may be damaged by ion milling and antiferromagnetism may fall, when nonmagnetic protective layer 29b is removed completely.
[0310] Next, the drawing 14 process is given. At the drawing 14 process, when middle antiferromagnetism layer 29a or nonmagnetic protective layer 29b is not removed completely, on left-behind nonmagnetic protective layer 29b, up antiferromagnetism layer 29c is formed in a vacuum, and continuation membrane formation of the protective layer 30 is further carried out in a vacuum. The spatter and vacuum deposition which were mentioned above can be used for membrane formation. Each class from the substrate layer 21 to a protective layer 30 constitutes Multilayers A.
[0311] It is specifically an above-mentioned PtMn alloy and a X-Mn alloy, or, as for the quality of the material used for up antiferromagnetism layer 29c, it is desirable the same antiferromagnetism ingredient of a presentation as the antiferromagnetism ingredient used for middle antiferromagnetism layer 29a and to be formed using a Pt-Mn-X' alloy.
[0312] Middle antiferromagnetism layer 29a, extant nonmagnetic protective layer 29b, and up antiferromagnetism layer 29c are united, and the 1st antiferromagnetism layer 29 consists of drawing 14 . When nonmagnetic protective layer 29b is removed completely, middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c are united, and the 1st antiferromagnetism layer 29 is constituted.
[0313] The comprehensive thickness which doubled the thickness of middle antiferromagnetism layer 29a and the thickness of up antiferromagnetism layer 29c is 500A or less in 80A or more. For example, it is 150A. As mentioned above, since thickness is as thin as 50A or less at 10A or more, if middle antiferromagnetism layer 29a is independent, it does not show antiferromagnetism, but it comes to show antiferromagnetism only after middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c are united, and produces a switched connection

field between the fixed magnetic layers 28.
[0314] Moreover, even when nonmagnetic protective layer 29b remains, the thickness of extant nonmagnetic protective layer 29b is as thin as 3A or less at 1A or more. Moreover, since it is formed by any one sort of Ru, Re, Pd, Os, Ir, Pt, Au, Rh, Cu, and the Cr, or two sorts or more Middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c are made to produce an antiferromagnetism-interaction, and it enables middle antiferromagnetism layer 29a, nonmagnetic protective layer 29b, and up antiferromagnetism layer 29c to function as an antiferromagnetism layer 29 of one. Moreover, even if the ingredient of nonmagnetic protective layer 29b is spread in middle antiferromagnetism layer 29a and up antiferromagnetism layer 29c, antiferromagnetism does not deteriorate.
[0315] Next, 2nd annealing in a magnetic field is given. The direction of a magnetic field at this time is the direction perpendicular to the truck cross direction of a leak field (the direction of illustration Y), i.e., the direction from a record medium. In addition, the 2nd [this] annealing in a magnetic field is smaller than the exchange anisotropy field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 in the 2nd impression field, and, moreover, makes heat treatment temperature lower than the blocking temperature of the 2nd antiferromagnetism layer 23. The exchange anisotropy field between the 1st antiferromagnetism layer 29 and the fixed magnetic layer 28 can be turned in the direction of a leak field (the direction of illustration Y) from a record medium, turning the direction of the exchange anisotropy field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 crosswise [truck] by this. Therefore, the magnetization direction of the fixed magnetic layer 28 is fixed in the direction which intersects the magnetization direction of the ferromagnetic layer 24 and the free magnetic layer 26.
[0316] In addition, the heat treatment temperature of the 2nd annealing in a magnetic field is 250 degrees C, and the magnitude of a field is 8-30 (kA/m) (kA/m), 24 [for example,]. The magnitude of the 2nd impression field is larger than the coercive force of 2nd fixed magnetic layer 28a and 1st fixed magnetic layer 28c, and smaller than the spin FUROPPU field between 2nd fixed magnetic layer 28a and 1st fixed magnetic layer 28c.
[0317] For this reason, by the 2nd above-mentioned annealing in a magnetic field, the 1st antiferromagnetism layer 29 regulation--ization-metamorphoses appropriately, and the switched connection field of magnitude suitable between the 1st antiferromagnetism layer 29 and the fixed magnetic layer 28 generates it.
[0318] Like the gestalt of this operation, Multilayers A are divided into two steps and membranes are formed, and if the manufacture approach of giving annealing in [2 times of] a magnetic field is used, the 1st antiferromagnetism layer 29 and the 2nd antiferromagnetism layer 23 can be formed using the antiferromagnetism ingredient which has the same presentation.
[0319] Next, at the process shown in drawing 15 , it leaves the resist layer R of the configuration shown in drawing 15 on a protective layer 30 by forming a resist layer in the top face of the protective layer 30 of Multilayers A, and carrying out exposure development of this resist layer. The resist layer R is a resist layer which has an undercut configuration for lift off, and has the width method of the truck cross direction equal to the truck width method Tw.

[0320] Next, by the ion milling from a perpendicular direction to the front face Ab of Multilayers A, the both-sides sections B and B of the multilayers A which are not covered with the resist layer R are deleted from a protective layer 30 to a part of 1st magnetic layer 26a of the free magnetic layer 26, as shown in drawing 16.
[0321] As a result of the ion milling of the drawing 16 process, from the protective layer 30 of Multilayers A to the middle of 1st magnetic layer 26a of the free magnetic layer 26 has the truck cross direction dimension of the truck width method Tw, and the truck cross direction dimension of the ferromagnetic layer 24 from the middle of 1st magnetic layer 26a, the 2nd antiferromagnetism layer 23, the seed layer 22, and the substrate layer 21 becomes larger than the truck width method Tw.
[0322] Moreover, the both-sides end faces Aa and Aa in the truck cross direction (the direction of illustration X) to a part of 1st magnetic layer 26a of the free magnetic layer 26 are perpendicular continuation sides from the protective layer 30 of Multilayers A to the front face Ab of Multilayers A. However, as shown by the dotted lines Aa1 and Aa1 of drawing 16, the both-sides end face in the truck cross direction from a protective layer 30 to a part of 1st magnetic layer 26a of the free magnetic layer 26 may be an inclined plane to the front face Ab of Multilayers A.
[0323] The insulating layers 32 and 32 which become the truck cross direction both-sides section from a protective layer 30 to the middle of 1st magnetic layer 26a of the free magnetic layer 26 from aluminum 2O3 or SiO2 are formed after ion milling process termination. In addition, the layer of the insulating material which constitutes insulating layers 32 and 32 adheres also to the top face and side face of the resist layer R. After forming insulating layers 32 and 32, the resist layer R is removed by the lift off using an organic solvent etc.
[0324] Furthermore, the up shielding layer 31 which makes an up electrode layer serve a double purpose is formed at the drawing 17 process on insulating layers 32 and 32 and the protective layer 30 of Multilayers A. In this way, the magnetic sensing element shown in drawing 1 is obtained.

[0325] After enlarging the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 and fixing the magnetization direction of the ferromagnetic layer 24 in the magnetization direction of the fixed magnetic layer 28, and the crossing direction strongly in this invention By making magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 smaller than said switched connection field the direction which single-domain-izes the free magnetic layer 26, and intersects the magnetization direction perpendicularly in the magnetization direction of the fixed magnetic layer 28 -- certain -- turning -- in addition -- and it is necessary to adjust so that it can leak and the magnetization direction of the free magnetic layer 26 can be fluctuated by the field
[0326] In order to enlarge the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24 and to make magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 smaller than a switched connection field At the drawing 12 process, the ferromagnetic layer 24 and the free magnetic layer 26 are formed so that the magnitude (Msxt) of the magnetic moment per unit area of the ferromagnetic layer 24 may become smaller than the magnitude (Msxt) of the magnetic moment per unit area of the free magnetic layer 26.
[0327] Specifically, the ratio (Msxt of Msxt / ferromagnetic layer 24 of a free magnetic layer) of the magnitude (Msxt) of the magnetic moment per [to the magnitude (Msxt) of the magnetic moment per unit area of the ferromagnetic layer 24] unit area of the free magnetic layer 26 is made into 20 or less range or more by three.
[0328] Moreover, the ferromagnetic layer 24, 2nd a little more than magnetic layer 24b which is the side which touches a non-magnetic layer 25 By forming by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) Magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 is moderately made small.
[0329] Moreover, the free magnetic layer 26, 1st magnetic layer 26a which is the side which touches a non-magnetic layer 25 By forming by the NiFe (permalloy) layer or NiFeX (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) Magnitude of the layer joint field between the free magnetic layer 26 and the ferromagnetic layer 24 is moderately made small.
[0330] According to the manufacture approach mentioned above, it will adjust in two steps, the magnitude of the switched connection field between the 2nd antiferromagnetism layer 23 and the ferromagnetic layer 24, and the magnitude of the layer joint field between the ferromagnetic layer 24 and the free magnetic layer 26, and single-domain-izing of the free magnetic layer 26 and fine control of the magnetization direction can be performed easily.
[0331] Therefore, since single-domain-izing of the free magnetic layer 26 and control of the magnetization direction can be performed appropriately and easily, the further narrow track-ization of a magnetic sensing element can be promoted.
[0332] moreover, the direction which crosses the magnetization direction of the free magnetic layer 26 in the magnetization direction of the fixed magnetic layer 28 also with the structure where the laminating of the ferromagnetic layer 24 and the 2nd antiferromagnetism layer 23 is carried out to the lower layer of width-of-recording-track field 26c of the free magnetic layer 26 through a non-magnetic layer 25 -- certain -- turning -- in addition -- and it becomes possible to leak and to fluctuate the magnetization direction of the free magnetic layer 26 by the field. Therefore, it will be hard to be in the condition that the magnetization directions of the free magnetic layer 26 differ, at the center section and both ends of width-of-recording-track field 26c of the free magnetic layer 26.
[0333] Moreover, since what is necessary is just to form layers for giving a vertical bias field to the free magnetic layer 26, such as a non-magnetic layer 25, the ferromagnetic layer 24, and the 2nd antiferromagnetism layer 23, in the shape of solid film at the drawing 12 process, and to delete the both-sides sections B and B of Multilayers A at drawing 15 and the drawing 16 process, a production process becomes easy. Moreover, since the precision of the truck width method Tw becomes good, narrow track-ization becomes easy.
[0334] The magnetic sensing element shown in drawing 4 thru/or drawing 9 can also be formed using the manufacture approach mentioned above and the same manufacture approach. Moreover, after the magnetic sensing element of drawing 11 first forms the 2nd antiferromagnetism layer 23, the ferromagnetic layer 24, a non-magnetic layer 25, and the free magnetic layer 60, After giving annealing in a magnetic field for magnetization control of the free magnetic layer 60 and processing each class from said 2nd antiferromagnetism layer 23 to said free magnetic layer 60 into abbreviation trapezoidal shape like drawing 11, After forming the non-magnetic material layer 27 and the fixed magnetic layer 28 on the both sides and forming the 1st antiferromagnetism layer 29 and the electrode layer 50 on said fixed magnetic layer 28 further, annealing in a magnetic field for magnetization control of the fixed magnetic layer 28 is given, and it is formed.
[0335] Moreover, in this invention, it can also consider as the magnetic sensing element called a tunnel mold magneto-resistive effect mold component by forming the non-magnetic material layer 27 of a magnetic sensing

element by insulating materials, such as aluminum 2O3 and SiO2.
[0336] In addition, the magnetic sensing element in this invention is not usable only to the thin film magnetic head carried in a hard disk drive unit, and is usable to the magnetic head for tapes, a magnetometric sensor, etc.
[0337] Although this invention was described about the desirable example above, various modification can be added in the range which does not deviate from the range of this invention.
[0338] In addition, the example mentioned above is instantiation to the last, and does not limit the claim of this invention.
[0339]
[Example] The magnetic sensing element by which the free magnetic layer 26 was formed above the fixed magnetic layer 28 like drawing 5 in this example is used. Various film configurations of said free magnetic layer 26 and film configurations of the ferromagnetic layer 24 are changed. The desirable quality of the material used for the free magnetic layer 26 and the ferromagnetic layer 24 at that time, And it investigated about the ratio (Msxt of Msxt / ferromagnetic layer 24 of the free magnetic layer 26) of the magnetic moment (Msxt) per [to the magnetic moment (Msxt) per unit area of the ferromagnetic layer 24] unit area of the free magnetic layer 26 etc.
[0340] First, in Table 1 shown below, it is the table showing the relation between the ratio (Msxt of Msxt / ferromagnetic layer 24 of the free magnetic layer 26) of the magnetic moment (Msxt) per [to the magnetic moment (Msxt) per unit area of the ferromagnetic layer 24 when changing the quality of the material and layer structure which constitute the free magnetic layer 26] unit area of the free magnetic layer 26, and the playback sensibility eta and a hysteresis.
[0341]
[Table 1]

	強磁性層24		フリー磁性層26					
	第1磁性層 10Å固定	第2磁性層 10Å固定	フリー①	フリー② トータル120Å固定	フリー③	磁性モーメントの比率	η (%)	ヒステリシス (%)
実施例1	$Co_{80}Fe_{12}Cr_{8}$	$Ni_{80}Fe_{20}$	$Ni_{80}Fe_{20}$ (20Å)	$Co_{90}Fe_{10}$ (100Å)		11.4	22	1.6
実施例2	↑	↑	$Ni_{85}Fe_{10}Nb_{5}$ (20Å)	$Co_{90}Fe_{10}$ (100Å)		10.8	32	0.9
実施例3	↑	↑	$Ni_{80}Fe_{20}$ (100Å)		$Co_{90}Fe_{10}$ (20Å)	7.8	24	1.2
実施例4	↑	↑	$Ni_{85}Fe_{10}Nb_{5}$ (100Å)		↑	5.6	19	0.8
実施例5	↑	↑	$Ni_{85}Fe_{10}Nb_{5}$ (20Å)	$Ni_{80}Fe_{20}$ (80Å)	$Co_{90}Fe_{10}$ (20Å)	7.9	28	0.5
実施例6	↑	↑	$Ni_{80}Fe_{20}$ (120)			7.0	21	0.9
実施例7	↑	↑	$Ni_{85}Fe_{10}Nb_{5}$ (120)			4.2	18	0.6
比較例1	↑	↑	$Co_{90}Fe_{10}$ (20Å)	$Ni_{80}Fe_{20}$ (80Å)	$Co_{90}Fe_{10}$ (20Å)	8.8	8	3.4
比較例2	↑	↑	$Co_{90}Fe_{10}$ (20Å)	$Ni_{85}Fe_{10}Nb_{5}$ (80Å)	↑	6.8	7	3.1
比較例3	↑	↑	$Co_{90}Fe_{10}$ (120)			12.8	9	6.5
比較例4	$Co_{90}Fe_{10}$		$Co_{90}Fe_{10}$ (20Å)	$Ni_{80}Fe_{20}$ (80Å)	$Co_{90}Fe_{10}$ (20Å)	4.4	6	3.2
比較例5	↑		$Co_{90}Fe_{10}$ (20Å)	$Ni_{85}Fe_{10}Nb_{5}$ (80Å)	↑	3.4	4	3.1
比較例6	↑		$Co_{90}Fe_{10}$ (120)			6.3	7	5.5

[0342] As shown in Table 1, in an example 1 thru/or 7 and the example 1 of a comparison thru/or 3, 1st a little more than magnetic layer 24a of the ferromagnetic layer 24 is formed at 10A Co80at%Fe12at%Cr8at%, and 2nd a little more than magnetic layer 24b is formed at 10A nickel80at%Fe20at%. Moreover, the ferromagnetic layer 24 is formed at 20A Co90at%Fe10at% the example 4 of a comparison thru/or 6.
[0343] Said free magnetic layer 26 is divided into three, "free **", "free **", and "free **", in the "free magnetic layer 26" column shown in Table 1. The layer of the side which touches the non-magnetic layer 25 indicated to be free ** to drawing 1 here is expressed, and the layer of the side which touches the non-magnetic material layer 27

indicated to be free ** to drawing 1 is expressed. Although "free **" expresses the interlayer of "free **" and "free **", it is the monolayer in which free ** and free ** coalesced, for example in the example 1, therefore the free magnetic layer 26 of an example 1 is two-layer structure. Such a view is the same about other examples in Table 1, the example of a comparison, and Table 2 or subsequent ones. Moreover, parenthesis writing indicated by each quality of the material of the free magnetic layer 26 of Table 1 is thickness.

[0344] In Table 1, the thickness of each class which constitutes the number of layers, the quality of the material, and the free magnetic layer 26 which constitute the free magnetic layer 26 was changed, and the ratio of the magnetic moment (Msxt) per [to the magnetic moment (Msxt) per unit area of the ferromagnetic layer 24 at that time] unit area of the free magnetic layer 26, the playback sensibility eta, and a hysteresis were searched for. In addition, the thickness of the free magnetic layer 26 is total, and it is set up so that it may become 120A.

[0345] Moreover, it asked for the playback sensibility eta by x(the maximum resistance variation obtained by impression field within the limits of the resistance variation / **5kOe to the impression field which assumed the leakage field from a record medium to be **40Oe) 100.

[0346] Moreover, the hysteresis was searched for by x(resistance variation in the impression field of the hysteresis resistance variation / **40Oe which remains at the zero of the hysteresis loop) 100.

[0347] In addition, 1Oe(s) (oersted) are about 79 A/m. Moreover, Table 2 or subsequent ones of how to search for the above-mentioned playback sensibility eta and a hysteresis is the same.

[0348] As shown in Table 1, it has the example 1 of a comparison thru/or the playback sensibility eta higher than 6, and the hysteresis also serves as a small value, and an example 1 thru/or 7 were understood that reproducing characteristics are good.

[0349] Next, in the following table 2, the quality of the material of 1st a little more than magnetic layer 24a which constitutes the ferromagnetic layer 24, and 2nd a little more than magnetic layer 24b was changed, and the ratio of the magnetic moment (Msxt) per [to the magnetic moment (Msxt) per unit area of the ferromagnetic layer 24 at that time] unit area of the free magnetic layer 26, the playback sensibility eta, and a hysteresis were searched for. In addition, both said 1st a little more than magnetic layer 24a and 2nd a little more than magnetic layer 24b are fixed to 10A thickness.

[0350] Moreover, the free magnetic layer 26 was made into two-layer structure by the example 2 and the example 8 thru/or 13, and 1st magnetic layer 26a was formed by 20A of nickel85at%Fe15at%Nb5at% of thickness (namely, only in case of free ** in Table 2). Moreover, 2nd magnetic layer 26b (namely, free ** and ** in Table 2) was formed by 100A of Co90at%Fe10at% of thickness. In addition, in the examples 14 and 15, it considered as the three-tiered structure and 1st magnetic layer 26a was formed at 20A of nickel85at%Fe10at%Nb5at% of thickness (namely, only in case of free ** in Table 2). Moreover, 2nd magnetic layer 26b (namely, free ** in Table 2) was formed by 20A of Co90at%Fe10at% of thickness. Furthermore, the middle magnetic layer (namely, free ** in Table 2) was formed by 80A of nickel80at%Fe20at% of thickness.

[0351]
[Table 2]

	強磁性層24		フリー磁性層26					
	第1磁性層 10Å固定	第2磁性層 10Å固定	フリー①	フリー② トータル120Å固定	フリー③	磁性モーメントの比率	η (%)	ヒステリシス (%)
実施例2	$Co_{80}Fe_{12}Cr_8$	$Ni_{80}Fe_{20}$	$Ni_{85}Fe_{10}Nb_5$ (20Å)	$Co_{90}Fe_{10}$ (100Å)		10.8	32	0.9
実施例8	$Co_{90}Fe_{10}$	↑	↑	↑		6.8	26	1.4
実施例9	$Co_{80}Fe_{12}Cr_8$	$Ni_{85}Fe_{10}Nb_5$	↑	↑		14.4	38	1.2
実施例10	$Co_{90}Fe_{10}$	↑	↑	↑		7.7	27	1.3
実施例11	$Co_{80}Fe_{12}Cr_8$		↑	↑		13.6	20	1.1
実施例12	$Co_{90}Fe_{10}$		↑	↑		5.6	12	0.8
実施例13	$Ni_{80}Fe_{20}$		↑	↑		8.9	22	2.3
実施例14	$Co_{80}Fe_{12}Cr_8$	$Ni_{80}Fe_{20}$	$Ni_{85}Fe_{10}Nb_5$ (20Å)	$Ni_{80}Fe_{20}$ (80Å)	$Co_{90}Fe_{10}$ (20Å)	7.9	28	0.5
実施例15	↑	$Ni_{85}Fe_{10}Nb_5$	↑	↑	↑	10.3	37	1.2

[0352] It turned out that all the examples shown in Table 2 have the high playback sensibility eta like the example shown in Table 1, and it is a value with a small hysteresis and excels in reproducing characteristics.

[0353] Next, in Table 3 shown below, the quality of the material of each class which constitutes the ferromagnetic layer 24 and the free magnetic layer 26 was fixed, and the thickness of 2nd magnetic layer 26b (namely, free ** and ** of Table 3) which constitutes said free magnetic layer 26 was changed gradually. Thickness formed 1st a little more than magnetic layer 24a which constitutes the ferromagnetic layer 24 as shown in following Table 3 at Co80at%Fe12at%Cr8at% which is 10A. Moreover, thickness formed 2nd a little more than magnetic layer 24b

which constitutes the ferromagnetic layer 24 at nickel80at%Fe20at% which is 10A. Thickness formed 1st magnetic layer 26a which furthermore constitutes the free magnetic layer 26 at nickel85at%Fe10at%Nb5at% which is 20A (namely, only in case of free ** shown in Table 3). Moreover, 2nd magnetic layer 26b which constitutes the free magnetic layer 26 was formed at Co90at%Fe10at%.

[0354]

[Table 3]

	強磁性層24		フリー磁性層26				
	第1磁性層 10Å固定	第2磁性層 10Å固定	フリー① $Ni_{85}Fe_{15}Nb_5$固定	フリー② フリー③ $Co_{90}Fe_{10}$固定	磁性モーメントの比率	η (%)	ヒステリシス (%)
実施例16	$Co_{80}Fe_{12}Cr_8$	$Ni_{80}Fe_{20}$	20Å	20Å	3.1	12	0.2
実施例17	←	←	←	40	5.0	15	0.4
実施例18	←	←	←	60	6.7	21	0.4
実施例19	←	←	←	80	9.0	27	0.8
実施例2	←	←	←	100	10.8	32	0.9
実施例20	←	←	←	120	12.7	37	1.2
実施例21	←	←	←	140	14.4	39	1.8
実施例22	←	←	←	160	16.5	43	2.4
実施例23	←	←	←	180	18.2	47	2.8
比較例7	←	←	←	5	1.1	2	0.1
比較例8	←	←	←	10	1.5	4	0.1
比較例9	←	←	←	15	2.4	9	0.1
比較例10	←	←	←	200	21.6	57	3.7
比較例11	←	←	←	300	31.5	62	5.2

[0355] Next, in Table 4 shown below, the quality of the material of each class which constitutes the ferromagnetic

layer 24 and the free magnetic layer 26 was fixed, and the thickness of 2nd a little more than magnetic layer 24b which constitutes said ferromagnetic layer 24 was changed gradually. Thickness formed 1st a little more than magnetic layer 24a which constitutes the ferromagnetic layer 24 as shown in following Table 4 at Co80at%Fe12at%Cr8at% which is 10A. Moreover, 2nd a little more than magnetic layer 24b which constitutes the ferromagnetic layer 24 was formed at nickel80at%Fe20at%. Thickness formed 1st magnetic layer 26a which furthermore constitutes the free magnetic layer 26 at nickel85at%Fe10at%Nb5at% which is 20A (namely, only in case of free ** shown in Table 3). Moreover, thickness formed 2nd magnetic layer 26b which constitutes the free magnetic layer 26 at Co90at%Fe10at% which is 100A.
[0356]
[Table 4]

	強磁性層24		フリー磁性層26					
	第1磁性層 $Co_{80}Fe_{12}Cr_{8}$ 固定	第2磁性層 $Ni_{80}Fe_{20}$ 固定	フリー① 20Å固定	フリー② 100Å固定	フリー③	磁性モーメントの比率	η (%)	ヒステリシス (%)
実施例24	10Å	2	$Ni_{85}Fe_{10}Nb_{5}$ (20Å)	$Co_{90}Fe_{10}$ (100Å)		19.2	46	2.8
実施例25	↑	4	↑	↑		16.6	43	2.5
実施例26	↑	6	↑	↑		14.2	38	2.2
実施例27	↑	10	↑	↑		10.5	35	1.4
実施例2	↑	20	↑	↑		10.8	32	0.9
実施例28	↑	30	↑	↑		4.4	21	0.8
実施例29	↑	40	↑	↑		3.4	14	0.7
比較例12	↑	0	↑	↑		26.7	59	4.4
比較例13	↑	1	↑	↑		24.5	53	3.4
比較例14	↑	50	↑	↑		2.9	8	0.5
比較例15	↑	60	↑	↑		2.6	7	0.5

[0357] It asked for the ratio (it is only hereafter called the ratio of the magnetic moment) of the magnetic moment (Msxt) per [to the magnetic moment (Msxt) per unit area of the ferromagnetic layer 24] unit area of the free magnetic layer 26 from Table 3 and 4 first.
[0358] It turns out that the ratio of the magnetic moment in each example shown in Table 3 and 4 is within the limits of 20 or less or more in three.
[0359] Although it is more desirable since it becomes easy to move a free magnetic layer sensitively to an external magnetic field as the ratio of the magnetic moment is large, if too large, a hysteresis will become large shortly, an

error rate becomes high, and it is obliged to the fall of reproducing characteristics.
[0360] For example, when the example 10 of a comparison shown in Table 3 and 11 are looked at, in these examples, the ratio of the magnetic moment is large and it turns out that the playback sensibility eta is over 50% for this reason. However, it turned out conversely that a hysteresis exceeds 3% and the hysteresis is getting worse compared with the example shown in Table 3.
[0361] Thus, the ratio of the magnetic moment has the need of asking from the playback sensibility eta and the both-sides side of a hysteresis. When the example shown in Table 3 and 4 is looked at, the ratio of the magnetic moment is 20 or less or more in three altogether. And the playback sensibility eta is 50% or less at 10% or more. Furthermore, a hysteresis is 3% or less.
[0362] Thus, by making the ratio of the magnetic moment or less into 20 by three or more showed that playback sensibility eta could be made to 50% or less at 10% or more, and a hysteresis could be made 3% or less, and good reproducing characteristics could be acquired.
[0363] Next, the desirable quality of the material and the layer structure of the free magnetic layer 26 and the ferromagnetic layer 24 are examined from Table 1 and 2.
[0364] For example, the ratio of the magnetic moment of the whole of the example 1 of a comparison shown in Table 1 thru/or 6 is within the limits of 20 or less or more in three. Although the ratio of this magnetic moment is within the limits of [desirable] this invention, the playback sensibility eta is 10% or less, and it is thought that the thing with a hysteresis higher than 3% is because 1st magnetic layer 26a of the free magnetic layer 26 is formed by CoFe.
[0365] 1st magnetic layer 26a of the free magnetic layer 26 produces association between layers between 2nd a little more than magnetic layer 24b of said ferromagnetic layer 24. Association between this layer must not be too strong. It is because it will be hard coming to carry out flux reversal of the free magnetic layer 26 to an external magnetic field, namely, will be obliged to the fall of the playback sensibility eta, if too strong.
[0366] However, if CoFe is used for 1st magnetic layer 26a of the free magnetic layer 26 as shown in Table 1, it will be thought that association between layers with 2nd a little more than magnetic layer 24b of the ferromagnetic layer 24 becomes strong. For this reason, although the ratio of the magnetic moment is desirable within the limits, the playback sensibility eta falls and a hysteresis is also further considered to become large.
[0367] This shows that it is more desirable for 1st magnetic layer 26a which constitutes the free magnetic layer 26 first not to use the ferromagnetic ingredient of Co system. When the example shown in Table 1 thru/or 4 is seen, the quality of the material currently altogether used for 1st magnetic layer 26a of the free magnetic layer 26 is the alloy of a NiFe system. For this reason, in this invention, it was presupposed that it is desirable to use a NiFe alloy or a NiFeX alloy (one sort or two sorts or more of elements with which X is chosen from aluminum, Si, Ti, V, Cr, Mn, Cu, Zr, Nb, Mo, Ru, Rh, Hf, Ta, W, Ir, and Pt) for 1st magnetic layer 26a of said free magnetic layer 26.
[0368] Next, although it is about the number of layers of the free magnetic layer 26, said free magnetic layer 26 may be formed by one layer, for example like the example 6 of Table 1, or an example 7, or said free magnetic layer 26 may be formed by two-layer like an example 1 thru/or 4, and said free magnetic layer 26 may be formed by the three-tiered structure still like an example 5.
[0369] However, it is more desirable to form the free magnetic layer 26 rather than one layer above two-layer. It is because it will become easy to diffuse nickel etc. to the non-magnetic material layer 27 shown in drawing 1 and will be easy to cause decline in magnetic-reluctance rate of change, if said free magnetic layer 26 is formed by the monolayer of a NiFe system like an example 6 or an example 7. For this reason, it is that the magnetic field which becomes the side which touches the non-magnetic layer 25 shown in drawing 1 as layer structure of the desirable free magnetic layer 26 from NiFe or NiFeX exists, and the magnetic field which consists of a ferromagnetic ingredient which contains Co (cobalt) in the side which touches said non-magnetic material layer 27 exists.
[0370] Next, although it is about the quality of the material of the ferromagnetic layer 24, in order not to not much strengthen association between layers with the free magnetic layer 26, it is desirable to form 2nd a little more than magnetic layer 24b of said ferromagnetic layer 24 with the alloy of a NiFe system. Almost all the examples shown in Table 1 thru/or 4 have such structure. However, even if it forms the ferromagnetic layer 24 whole with the ferromagnetic ingredient of a CoFe system like an example 11 or an example 12, the ratio of the magnetic moment is or less in 20 by three or more, and there are also the playback sensibility eta and a hysteresis within desirable limits.
[0371] Especially the ferromagnetic layer 24 generates a big switched connection field between the 2nd antiferromagnetism layers 23 shown in drawing 1, and magnetization must be firmly fixed in the fixed direction. Therefore, it is making it the magnetic field which consists of a ferromagnetic ingredient which contains Co in the side which touches the 2nd antiferromagnetism layer 23 as selection of the desirable quality of the material to the ferromagnetic layer 24 exist.
[0372] Moreover, 1 layer structure is sufficient like the example 11 shown in Table 2 thru/or 13 as a number of layers of said ferromagnetic layer, and you may be two-layer structure. Or you may be more than a three-tiered

structure.

[0373] However, it is thought that it is desirable that it is two-layer structure at least as for said ferromagnetic layer 24. The reason is that the direction formed the magnetic field which becomes the side which touches a non-magnetic layer 25 from NiFe or NiFeX can manufacture the magnetic sensing element which was more excellent in reproducing characteristics in order to form the magnetic field which consists of a ferromagnetic ingredient which contains Co in the side which touches the 2nd antiferromagnetism layer 23 in order to generate a big switched-connection field between the 2nd antiferromagnetism layers 23 and to, weaken moderately association between layers with the free magnetic layer 26 on the other hand.

[0374]

[Effect of the Invention] According to this invention explained to the detail above, it is turned in the direction where the magnetization direction of said ferromagnetic layer intersects the magnetization direction of said fixed magnetic layer by the switched connection field with said 2nd antiferromagnetism layer. Since the laminating of said free magnetic layer is carried out to said ferromagnetic layer through said non-magnetic layer, single-domain-izing of said free magnetic layer, and control of the magnetization direction It will be adjusted in two steps, the magnitude of the switched connection field between said antiferromagnetism layers and said ferromagnetic layers, and the magnitude of magnetic association between said ferromagnetic layers and said free magnetic layers, and fine control can be performed easily.

[0375] Therefore, in this invention, since single-domain-izing of said free magnetic layer and control of the magnetization direction can be performed appropriately and easily, the further narrow track-ization of a magnetic sensing element can be promoted.

[0376] moreover, the direction which intersects perpendicularly the magnetization direction of said free magnetic layer in the magnetization direction of said fixed magnetic layer by this invention also with the structure where the laminating of said ferromagnetic layer and said 2nd antiferromagnetism layer is carried out through said non-magnetic layer on the width-of-recording-track field of said free magnetic layer -- certain -- turning -- in addition -- and it becomes possible to leak and to fluctuate the magnetization direction of said free magnetic layer by the field.

[0377] Moreover, in this invention, said free magnetic layer can be single-domain-ized by the layer joint field through said non-magnetic layer with said ferromagnetic layer, and the magnetization direction can be turned in the magnetization direction of said fixed magnetic layer, and the crossing direction.

[0378] For example, between said free magnetic layers and said ferromagnetic layers, the RKKY interaction through said non-magnetic layer occurs. Consequently, said free magnetic layer single-domain-izes, and the magnetization direction is turned in the magnetization direction of said fixed magnetic layer, and the crossing direction.

[0379] Thus, in this invention, since single-domain-izing of said free magnetic layer and control of the magnetization direction are performed by the layer joint field through said non-magnetic layer with said ferromagnetic layer, the vertical bias field concerning said free magnetic layer can control that turbulence and the magnetic-domain structure of said free magnetic layer are disturbed by external magnetic fields, such as a leak field from a record medium.

[Translation done.]

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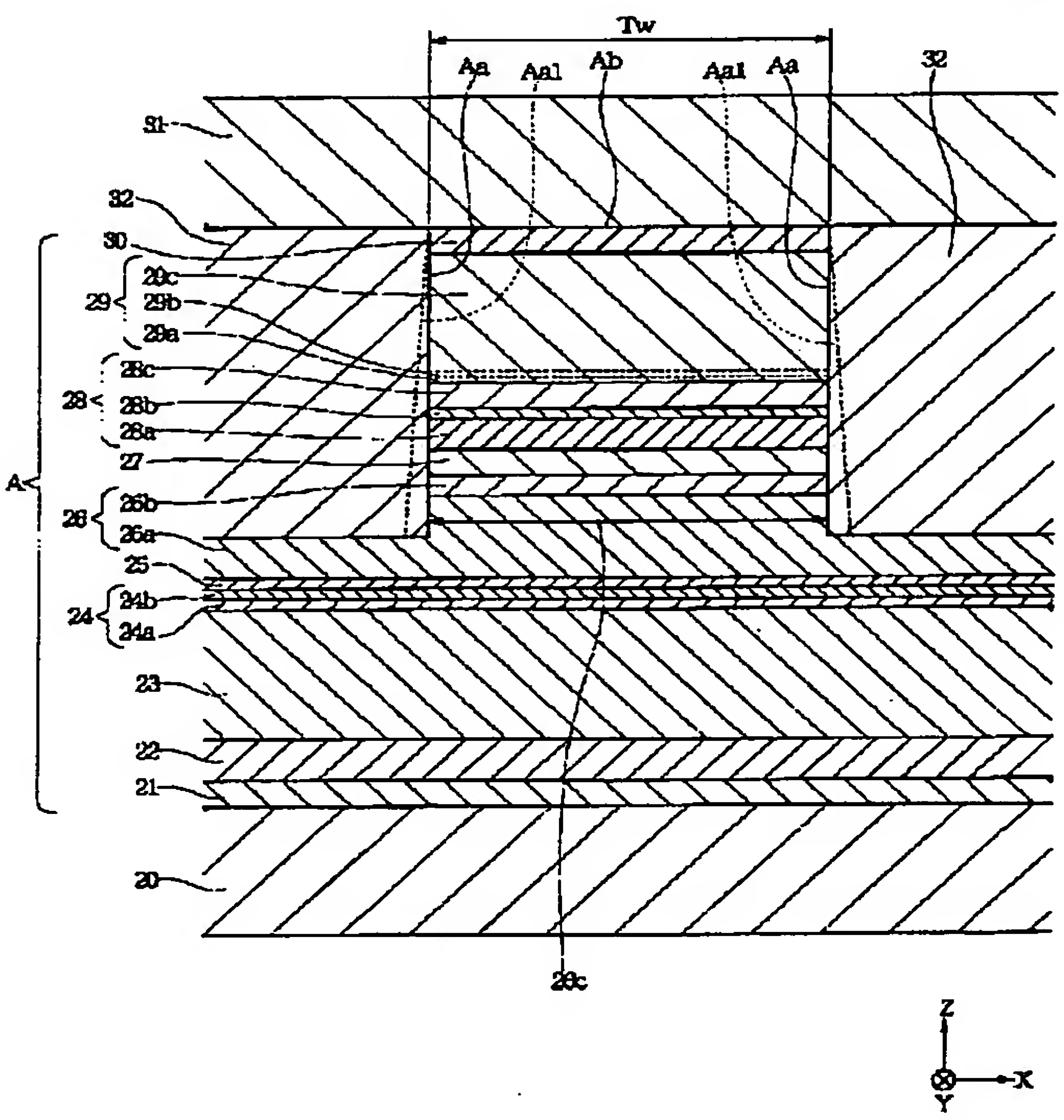
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

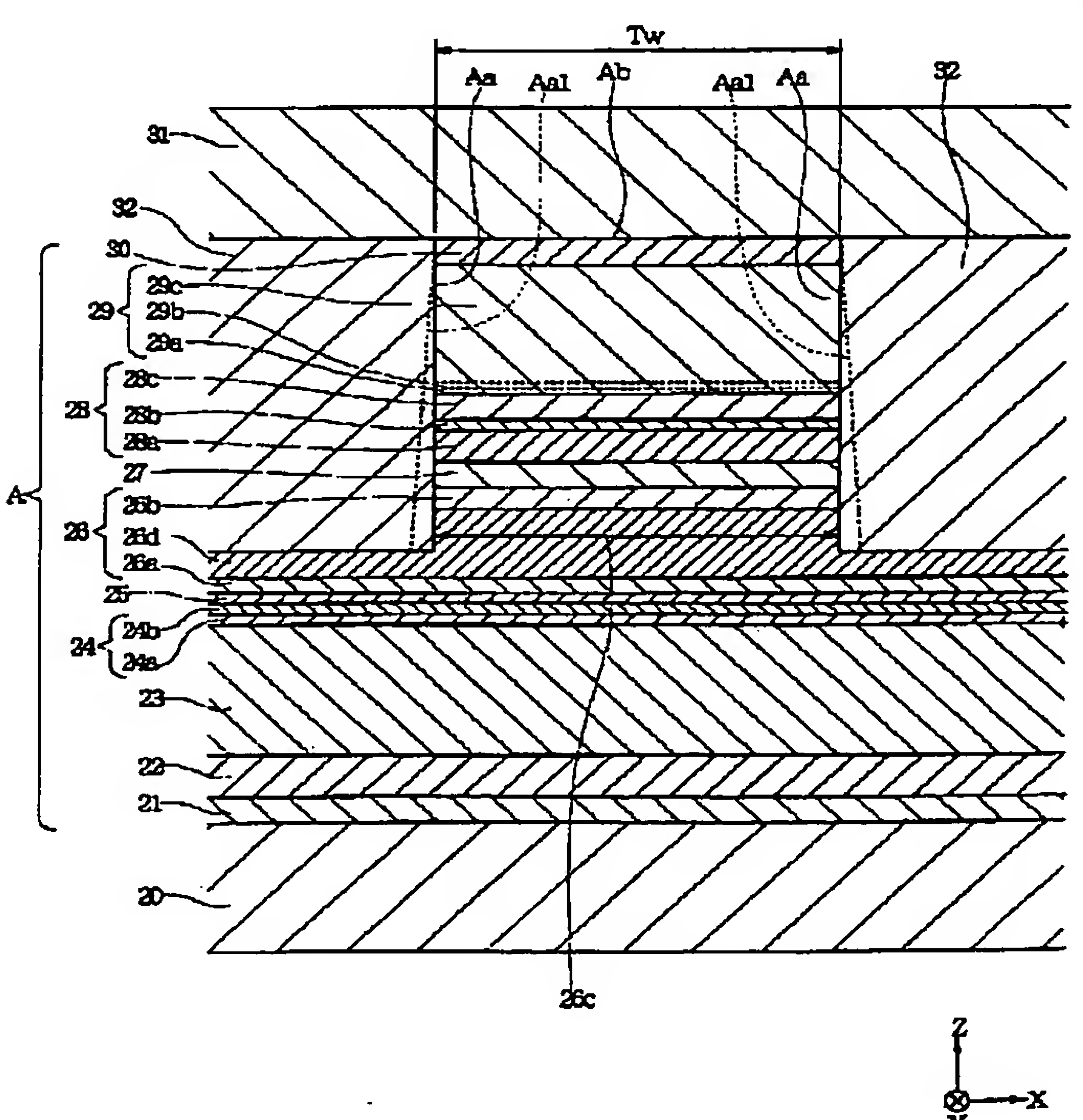
[Drawing 1]

図1



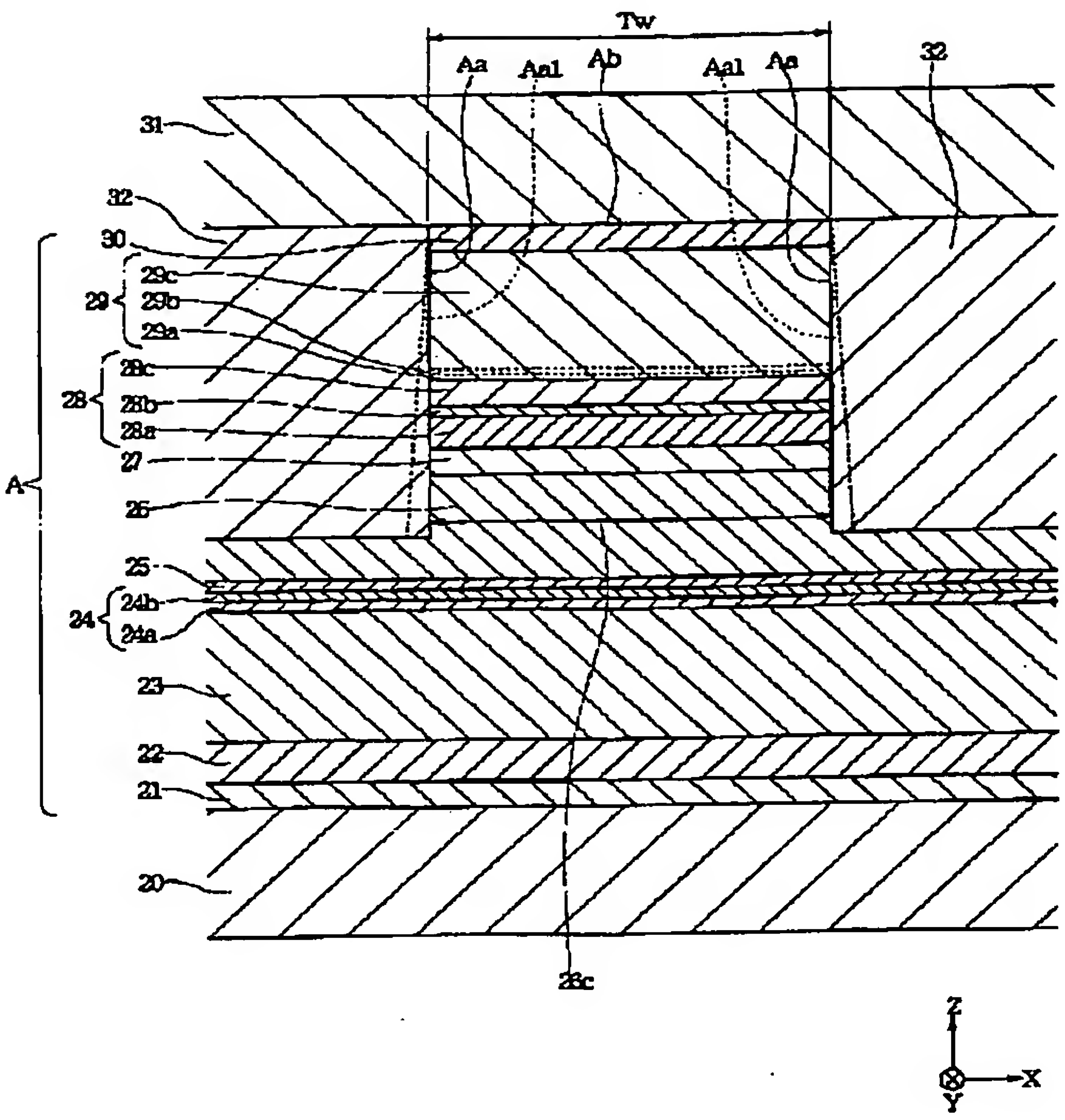
[Drawing 2]

図2



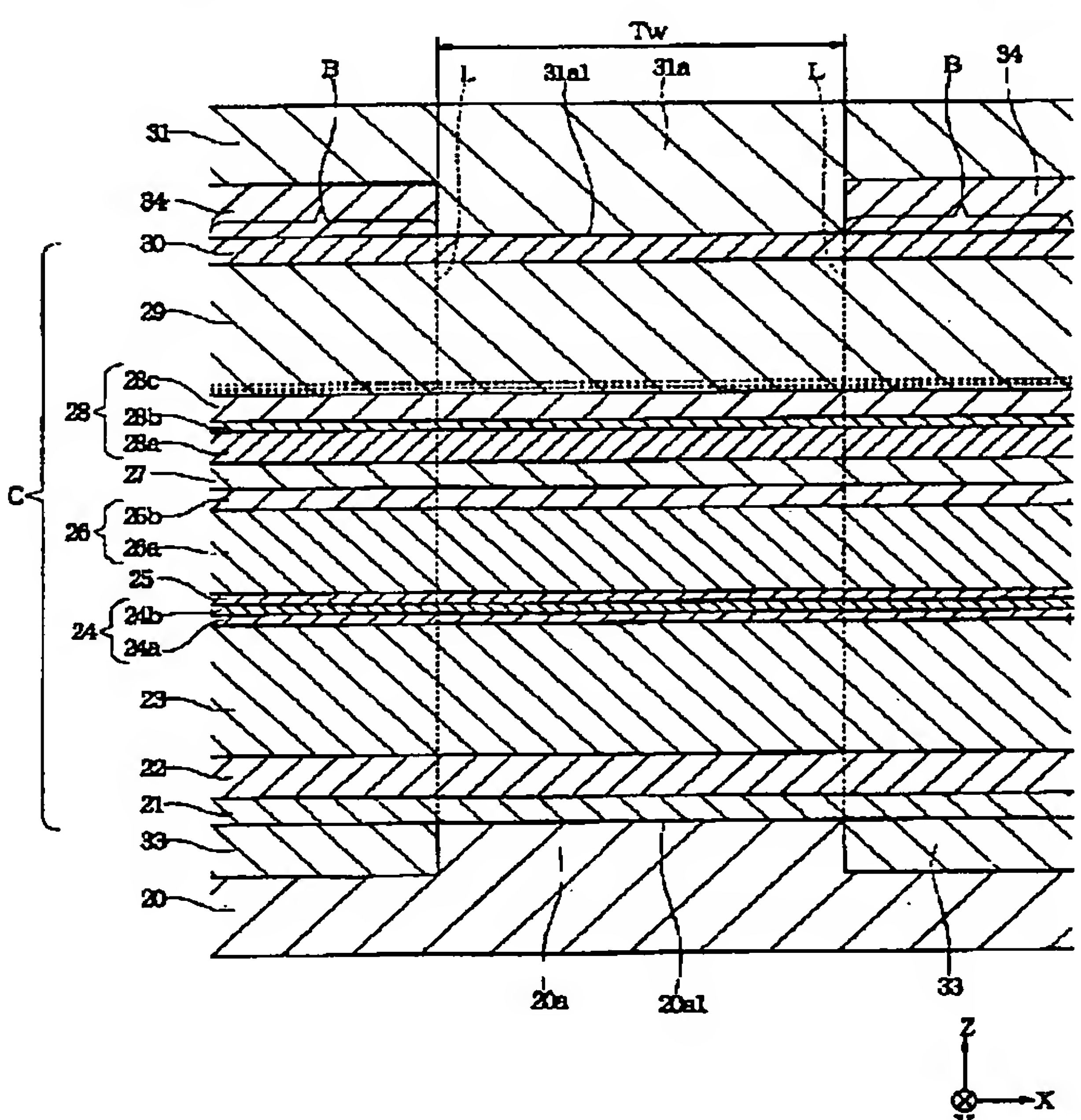
[Drawing 3]

図3



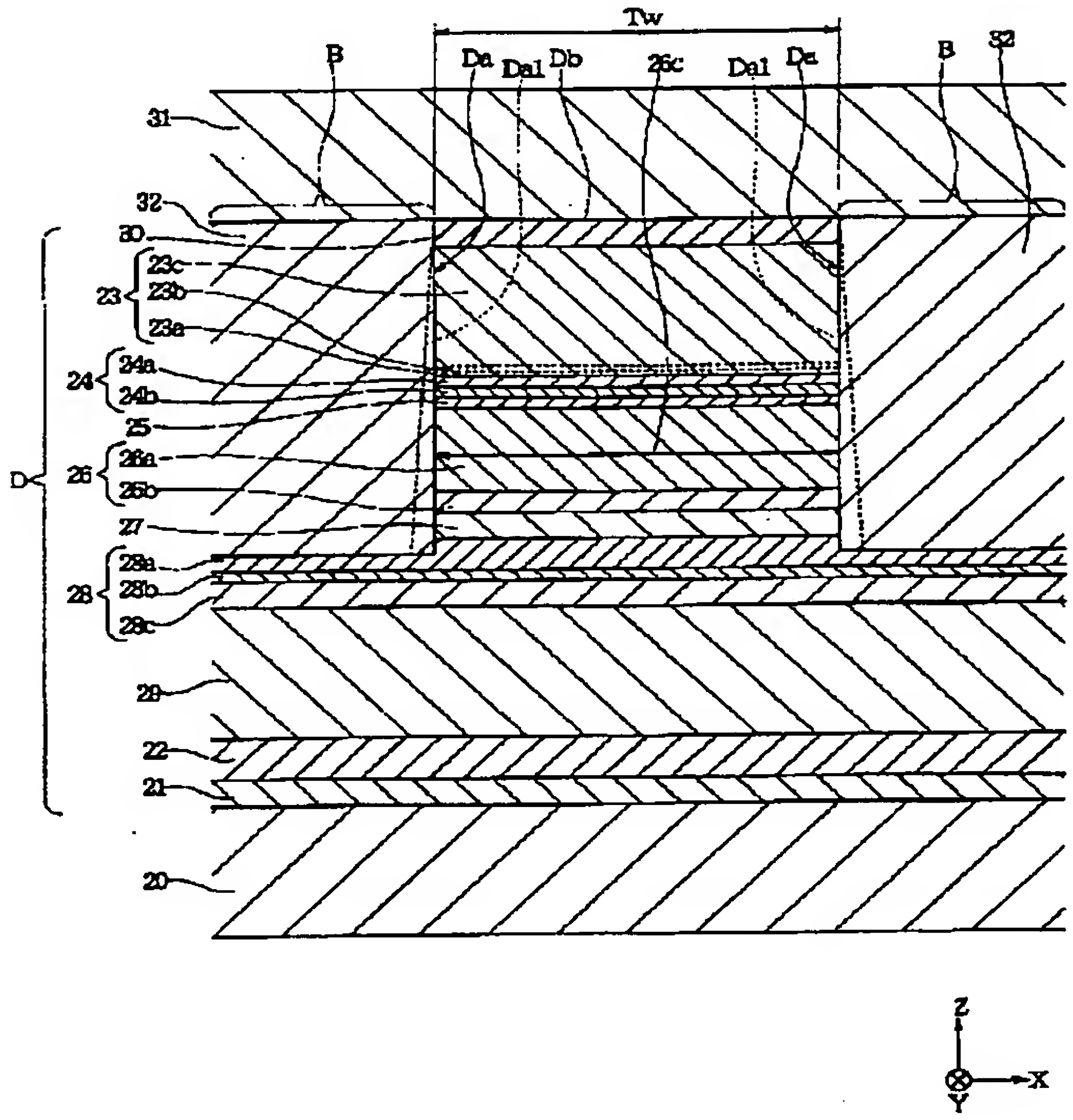
[Drawing 4]

図4



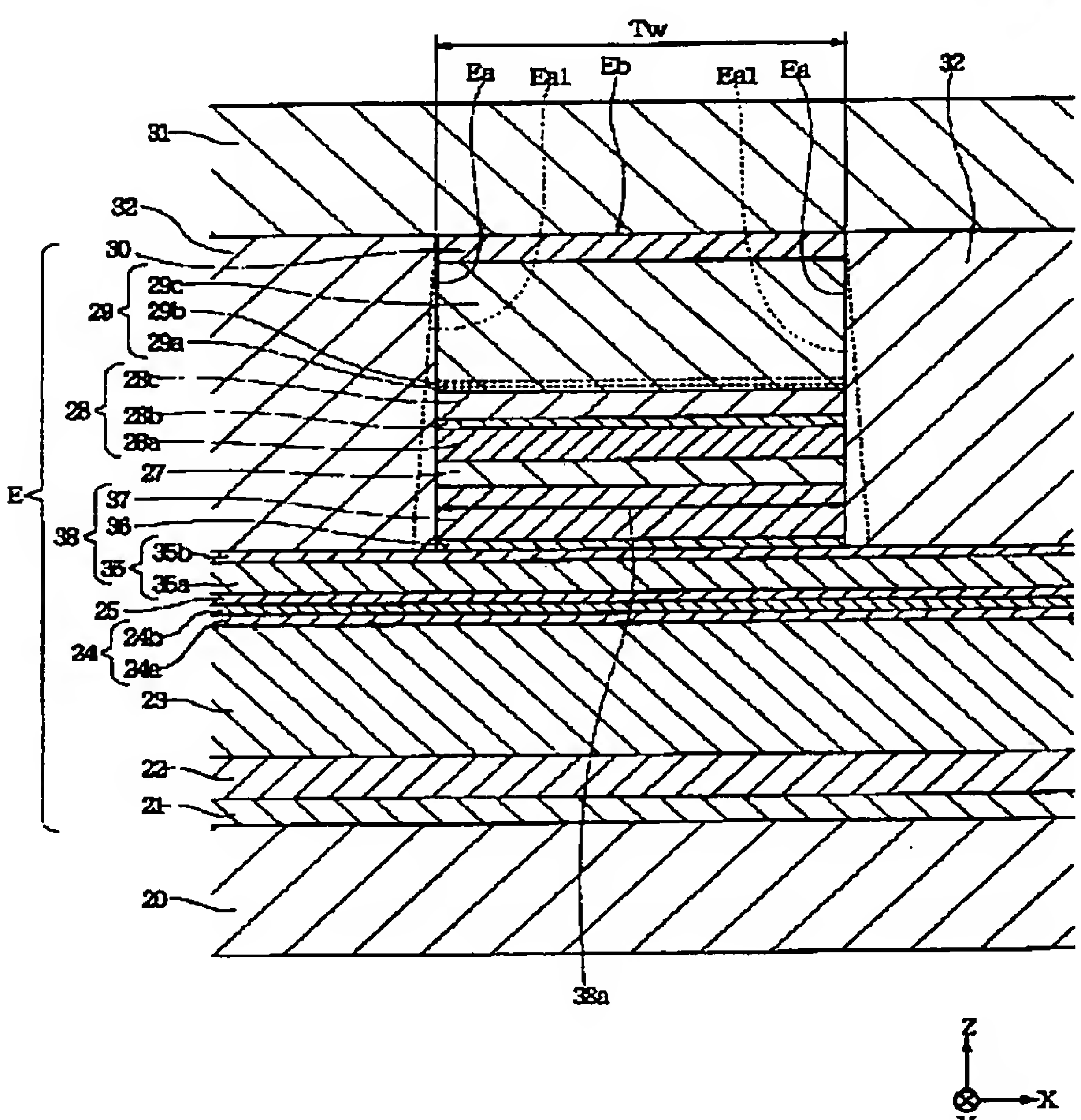
[Drawing 5]

図5



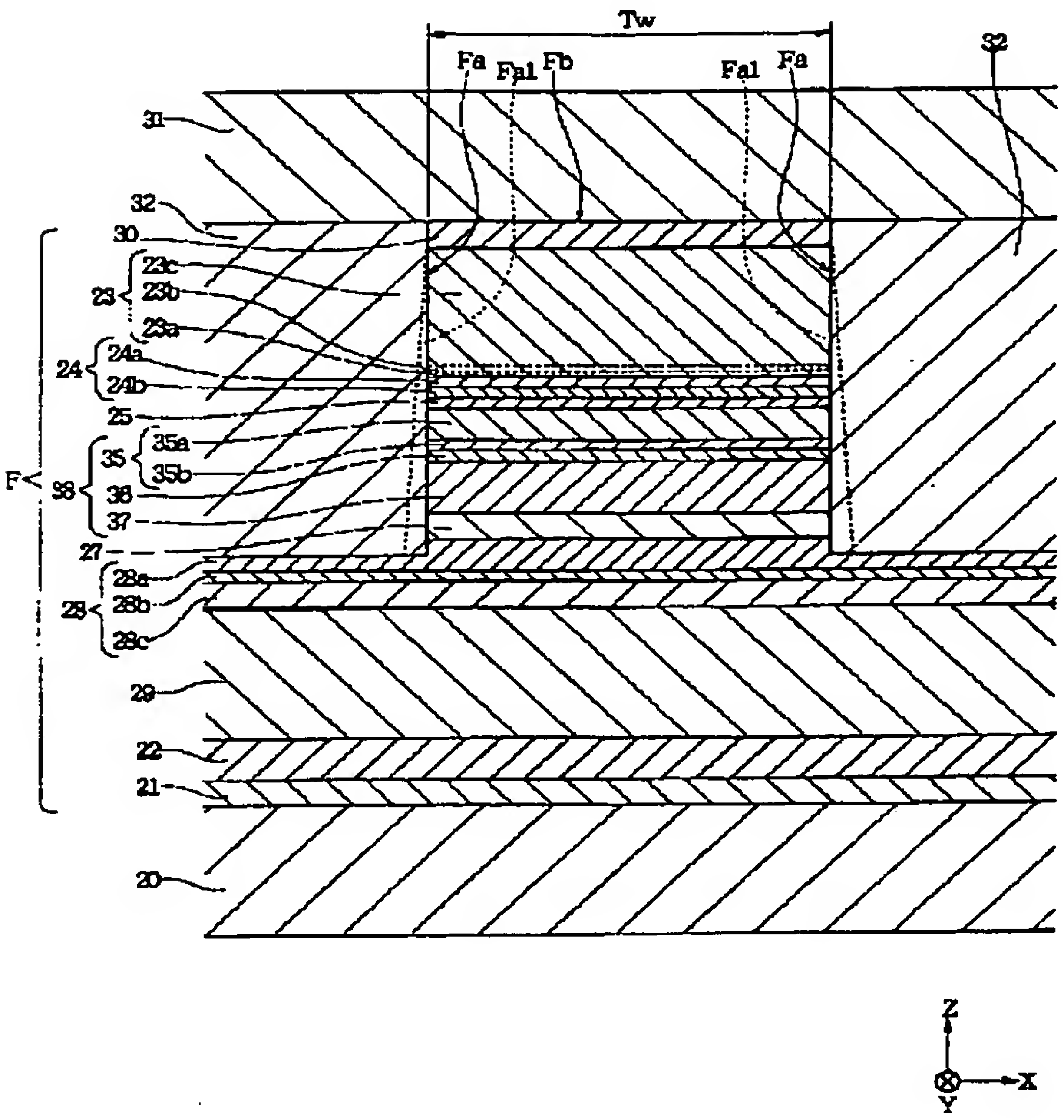
[Drawing 6]

図6



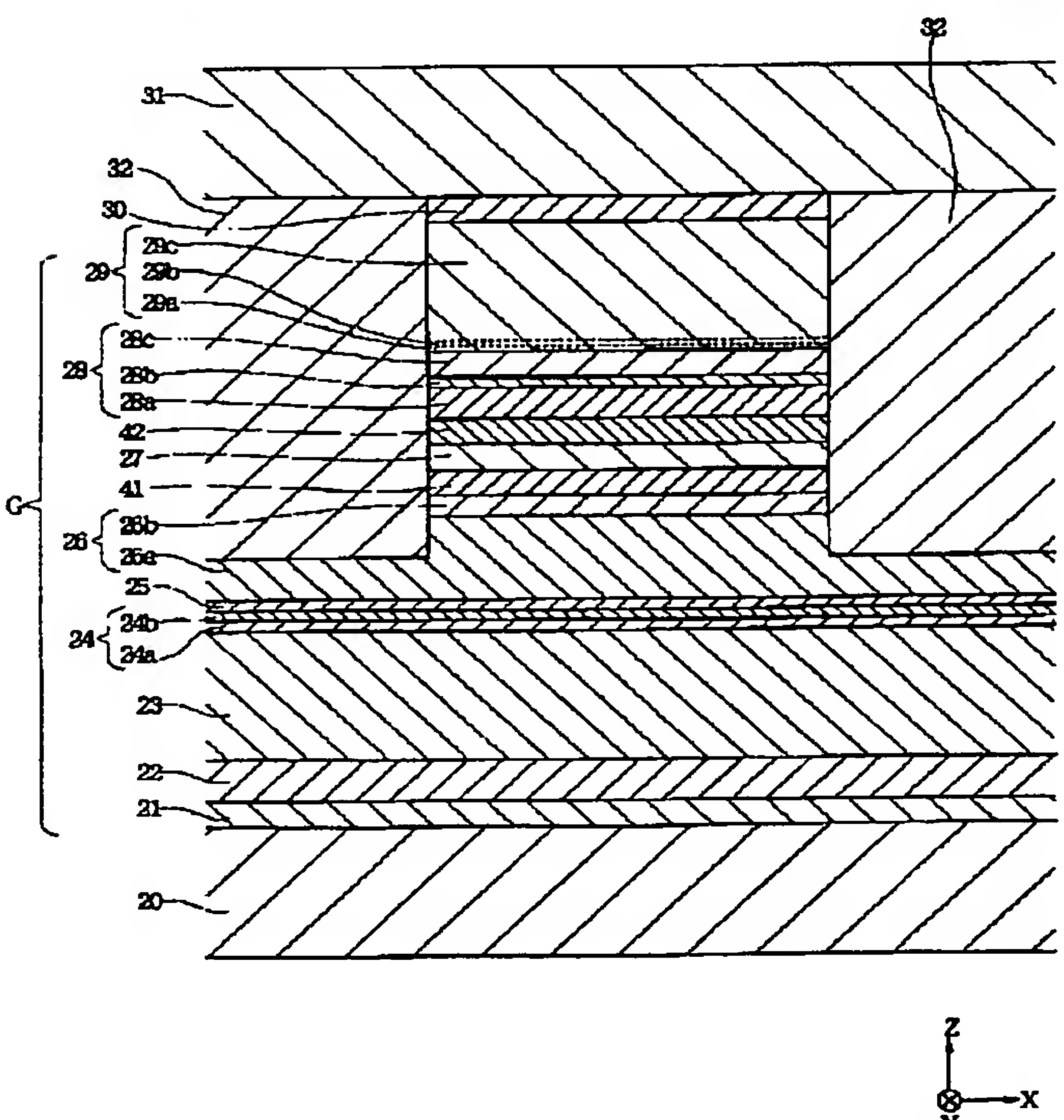
[Drawing 7]

図7



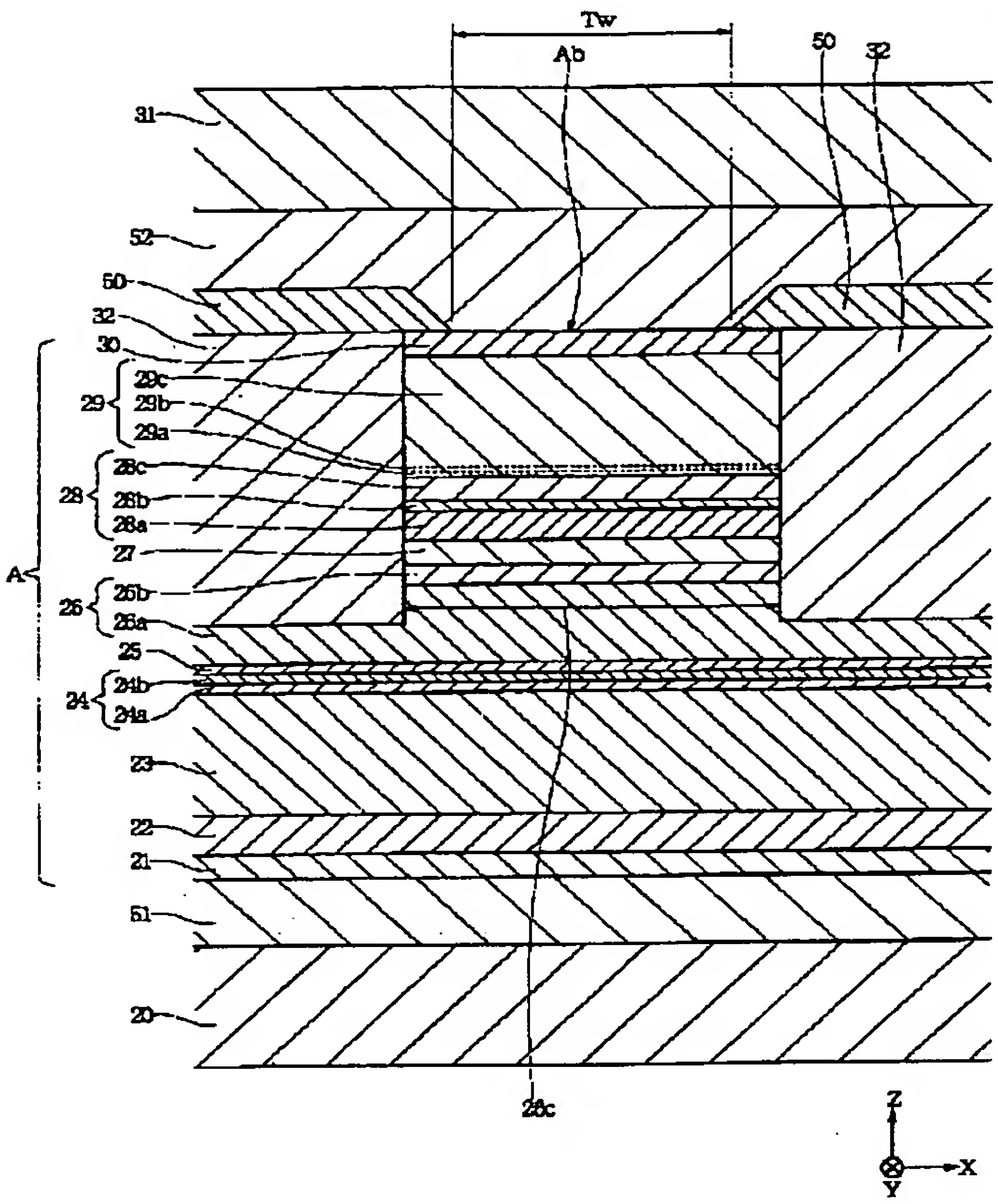
[Drawing 8]

図8



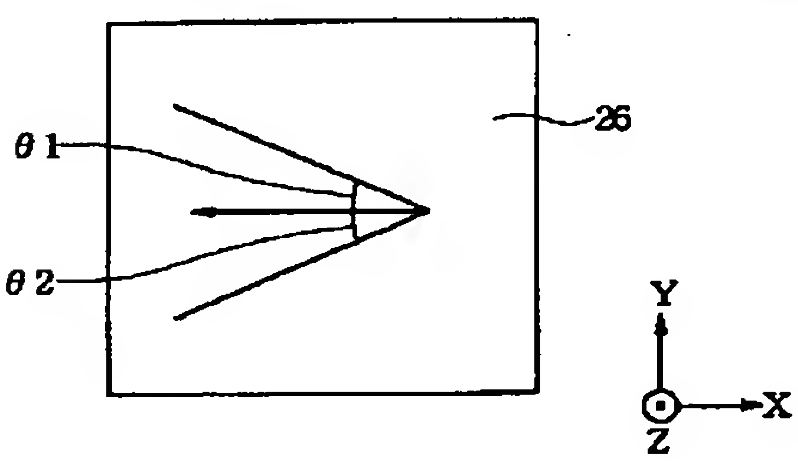
[Drawing 9]

図 9



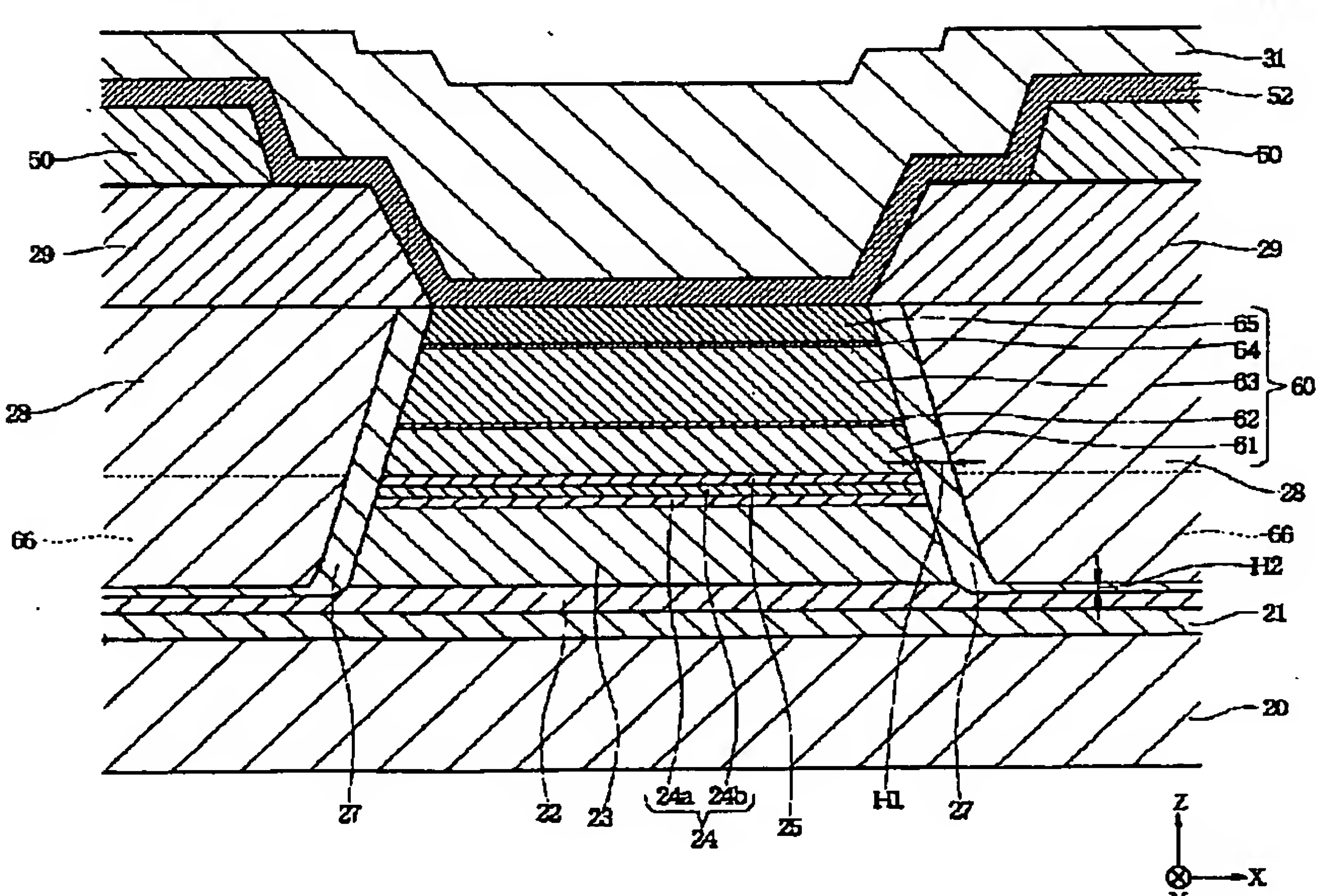
[Drawing 10]

図 10



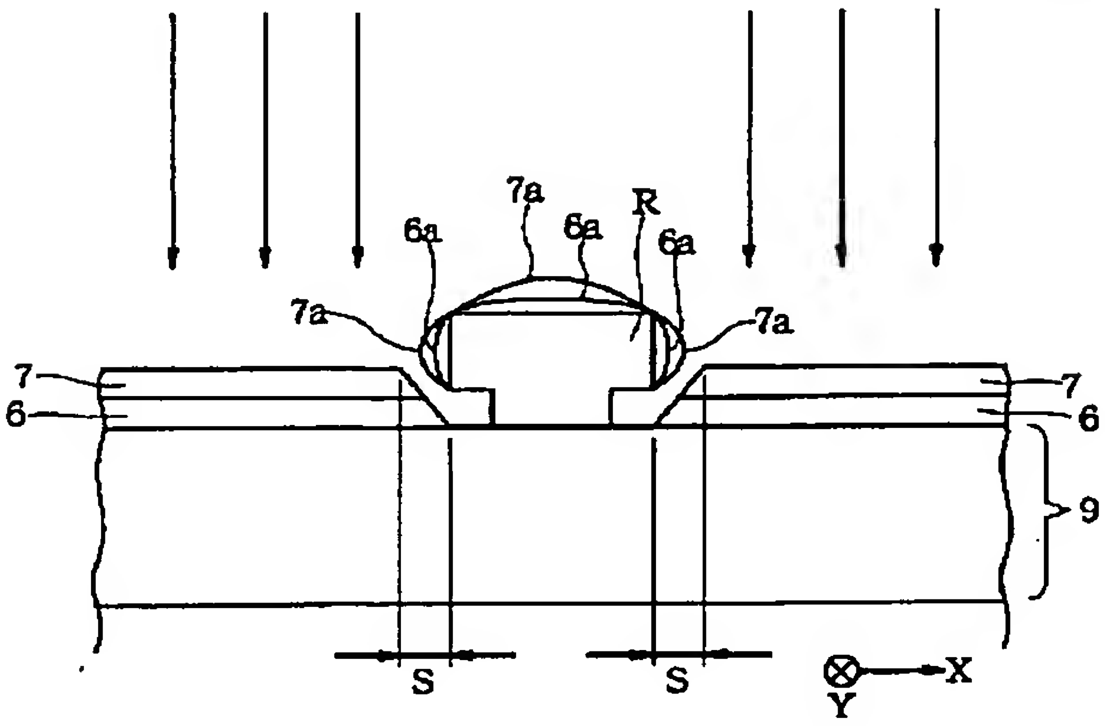
[Drawing 11]

図 11



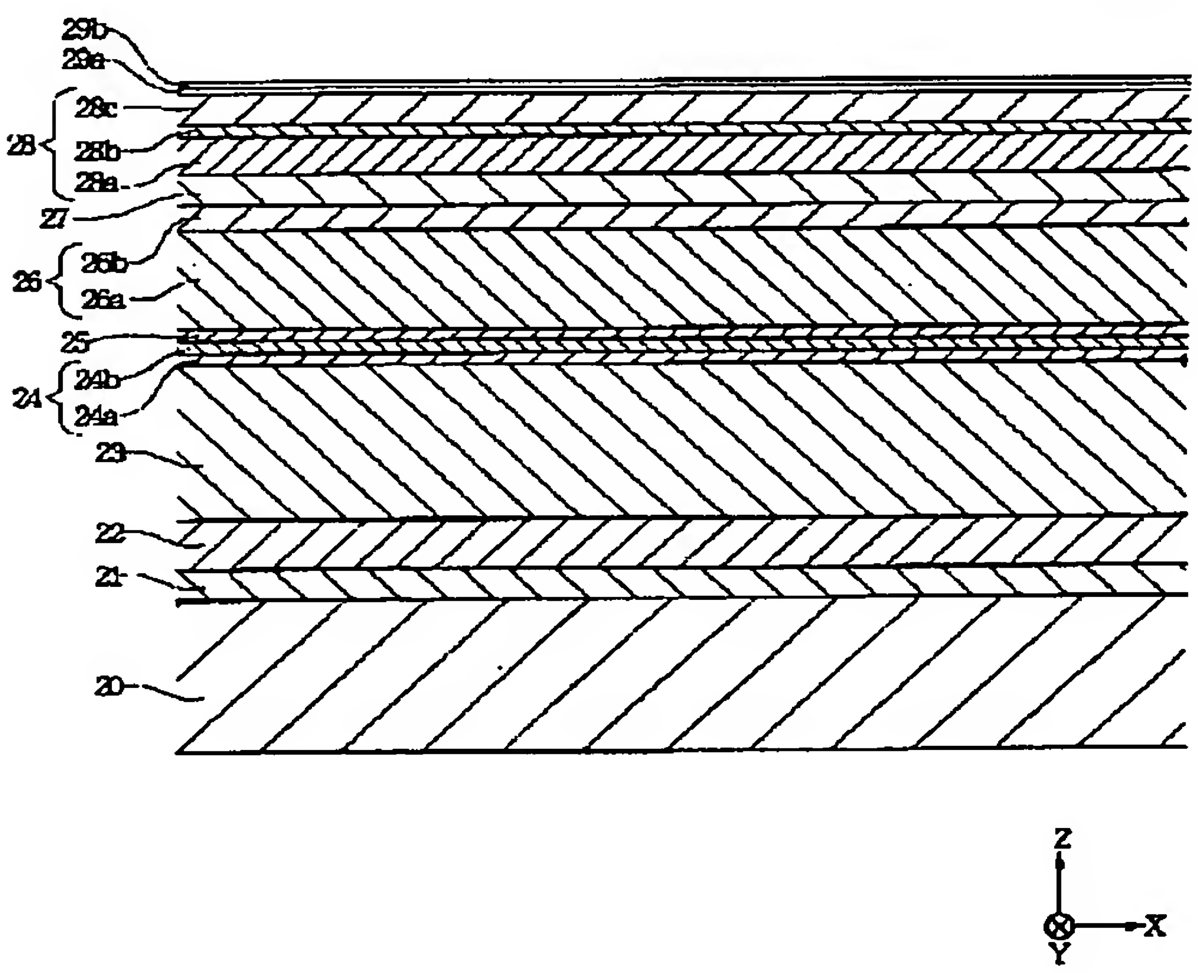
[Drawing 19]

図 19



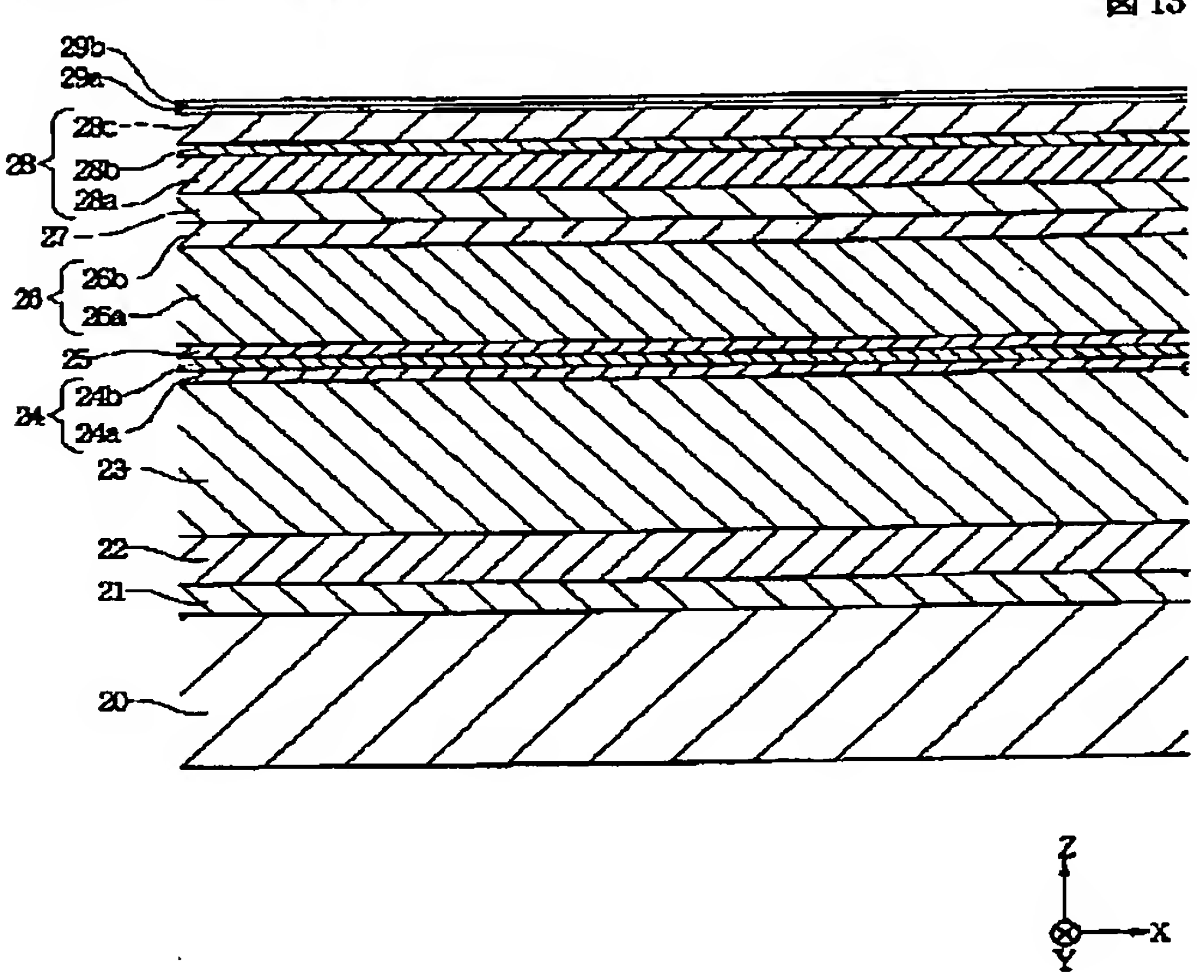
[Drawing 12]

図 12



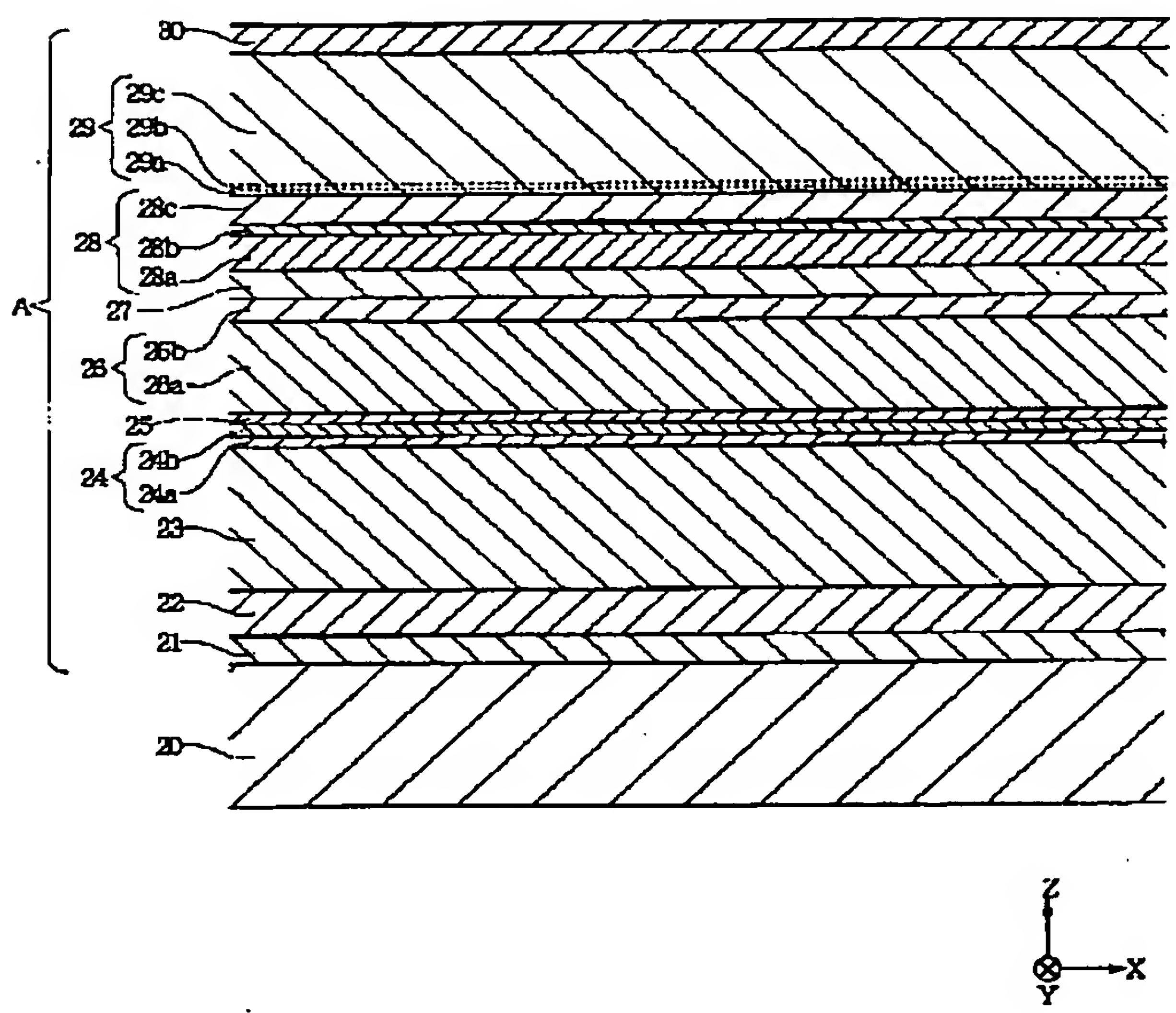
[Drawing 13]

図 13



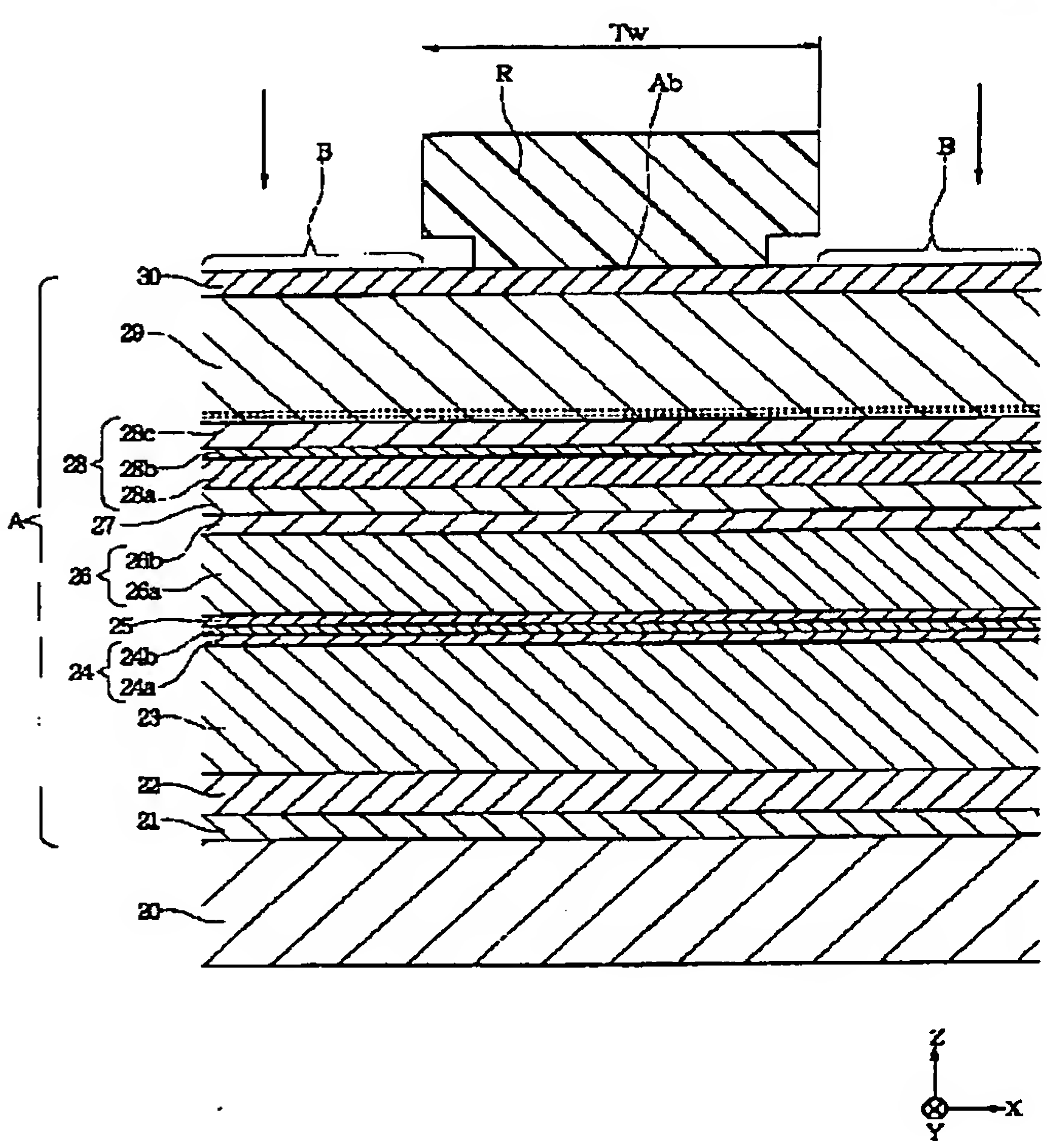
[Drawing 14]

図 14



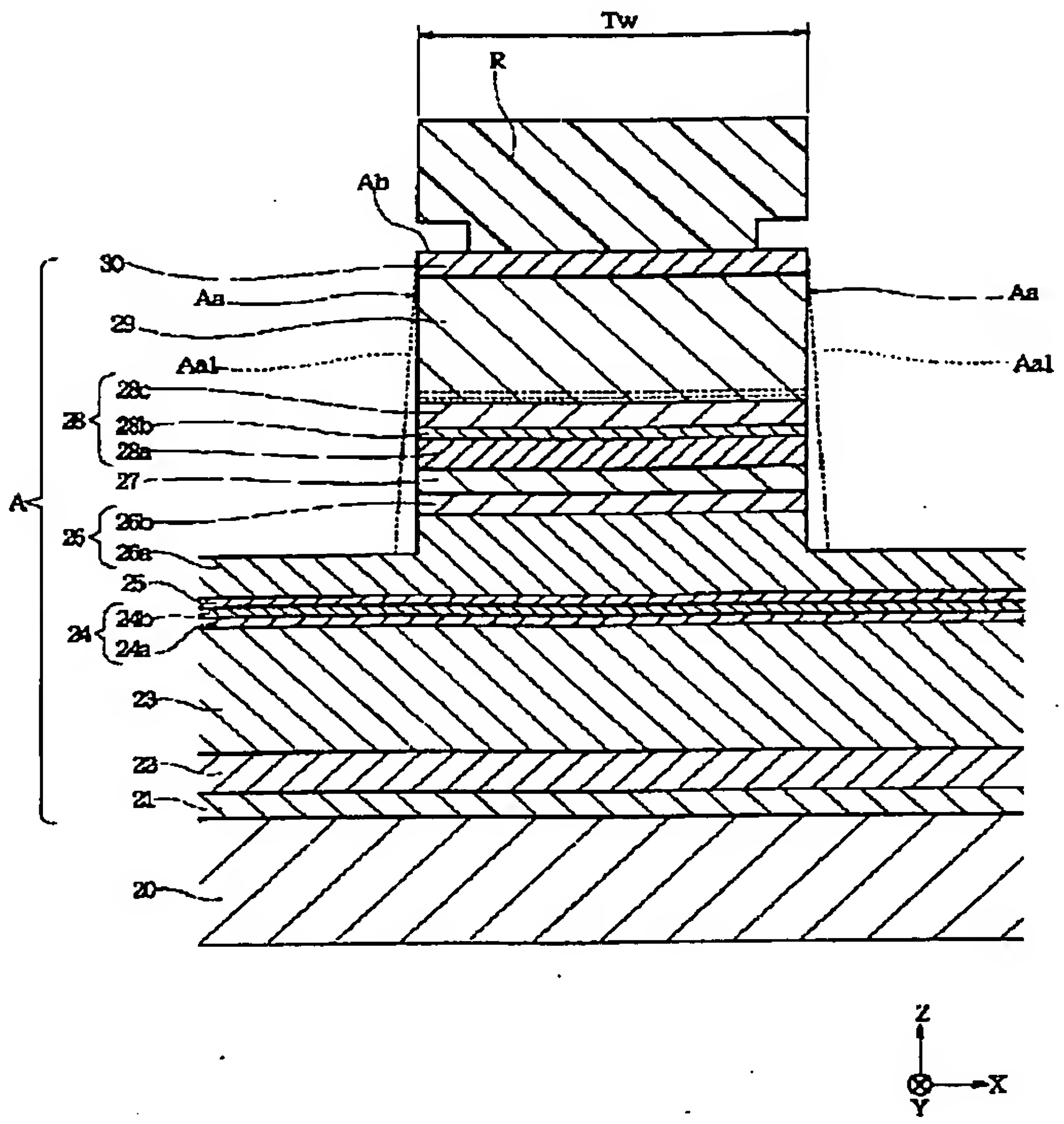
[Drawing 15]

図 15



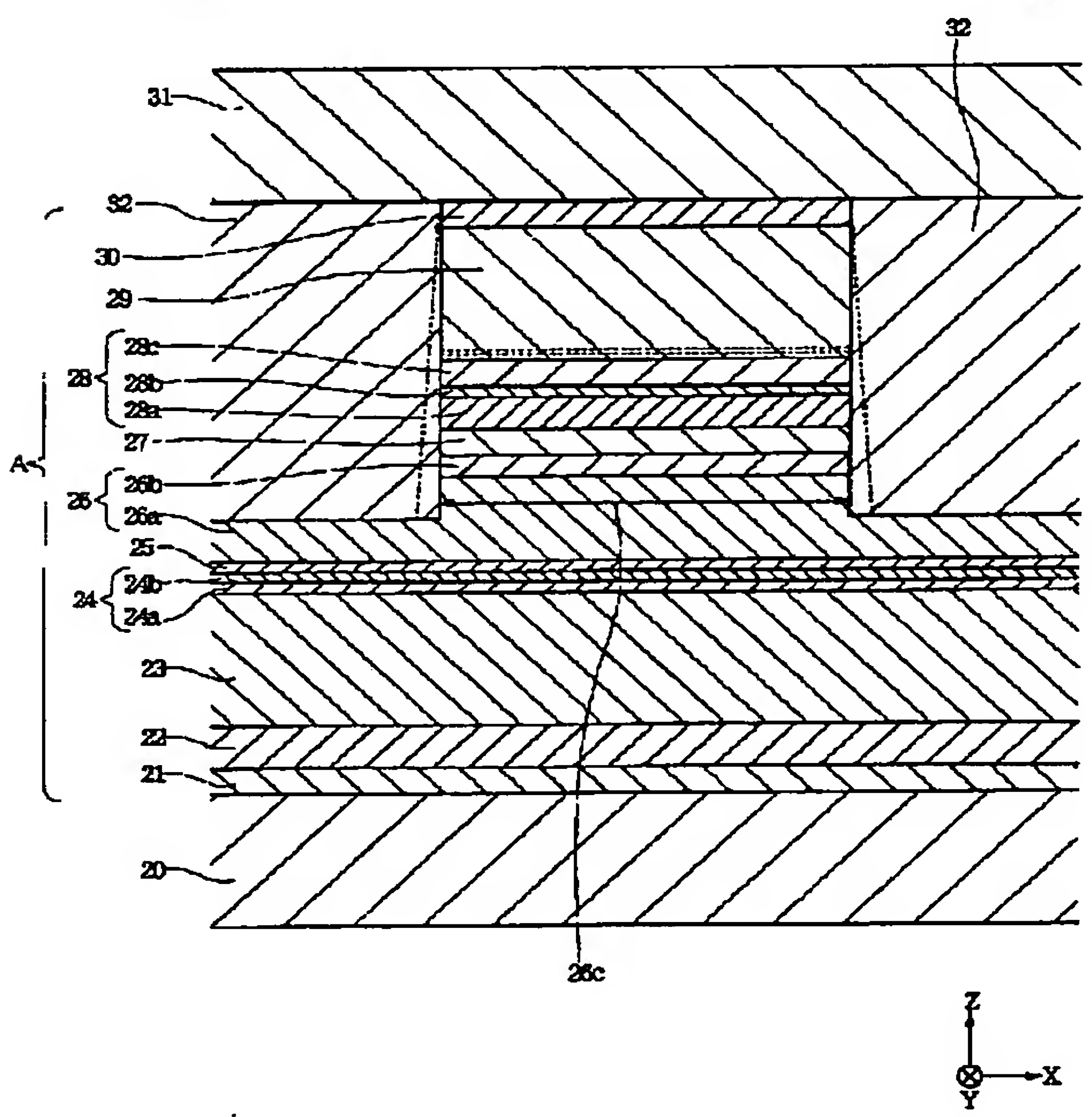
[Drawing 16]

図 16



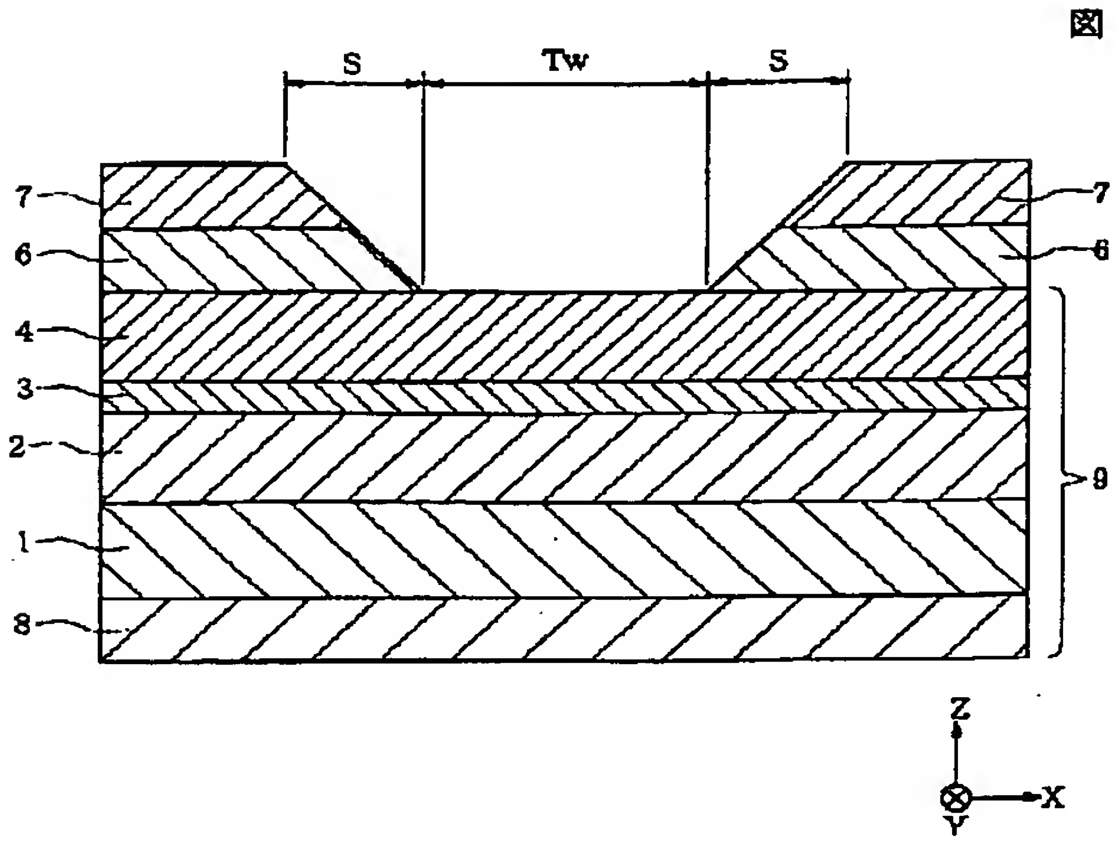
[Drawing 17]

図 17



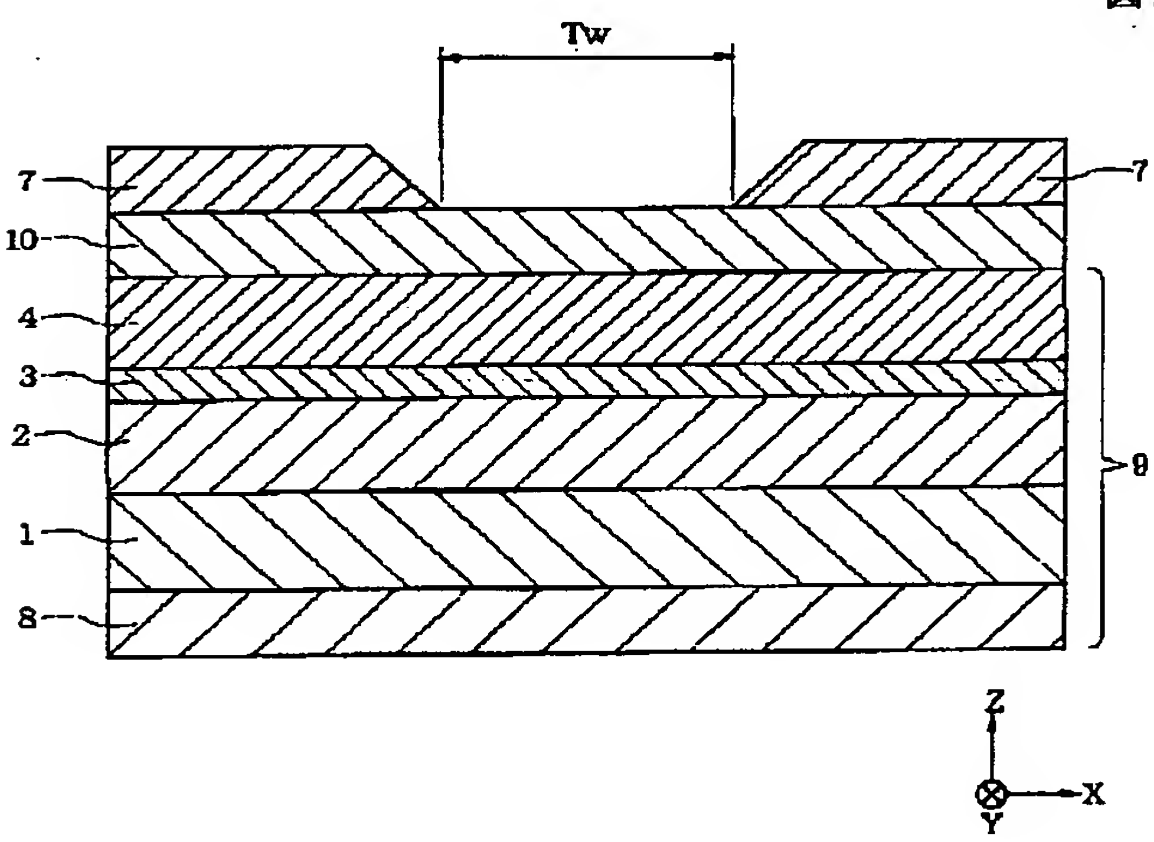
[Drawing 18]

図 18



[Drawing 20]

図 20



[Translation done.]